

RESEARCH ACTIVITIES IN ANIMAL PHYSIOLOGY AND LIVESTOCK SYSTEMS AT INRA (FRENCH NATIONAL INSTITUTE FOR AGRONOMIC RESEARCH)

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Abstract

INRA Animal Physiology and Livestock Systems Division (PHASE) forms a large scientific community (>500 scientists, >1200 workers) concerned by biology, physiology and animal sciences having animal production and food qualities as endpoints. PHASE should propose ecologically intensive systems of animal production maintaining farmer income. In 2007, French animal productions represented 17% of the total European (UE25) animal production, being leader for bovine and poultry. During the last 30 years, there was specialization, concentration and intensification of the animal production system. In parallel, consumers gave more importance to safety, quality, and specificity of products, to ethical and environmental considerations resulting in new European regulations. Sequencing of genomes, wide transcriptomic, proteomic and metabolomic approaches has opened the way to integrative biology. The PHASE priorities are therefore functional genomics, sustainable development of agriculture, knowledge and acceptability of biotechnologies, animal welfare, meat, milk and egg qualities for human feed. The objectives are to maintain France and Europe among the leaders of animal productions and to increase our scientific knowledge on the biology and breeding of fish, birds and mammals within their farming systems. PHASE aims to develop techniques for sustainable livestock systems and to understand the fundamental mechanisms of physiological functions which shape the phenotype and qualities of animal products. For information see <http://www.international.inra.fr/> and <http://www.inra.fr/compact/nav/externe/en/departements/ecrans/17>.

Keywords: animal physiology, product, sustainability, food

INTRODUCTION AND SOCIO-ECONOMICAL CONTEXT

INRA Animal Physiology and Livestock Systems Division (PHASE) division forms a large scientific community which includes biology, physiology and animal sciences and has animal production and food qualities as endpoints.

The **first** element of context is the expected explosion of human population (9 billions) which will need to be fed and the recognition that we are using a limited natural system. Animal products should come from environmentally friendly systems preserving the environment. We should propose ecologically intensive systems and take into account the consequences of global change on livestock systems. The **second** element is the competitiveness of animal production systems, in order to maintain

farms and farmers with a sufficient degree of income and autonomy. In 2007, French animal productions represented 17% of the total European (UE25) animal production. In particular, France is the leader for bovine and poultry meat and eggs. During the last 30 years, there was specialization, concentration and intensification of the animal production system. In parallel, consumer demand changed greatly, giving importance to quality, ethical and environmental considerations stressed in Europe through new regulations. The **third** element is the need to ensure that animal products are safe and appropriate for human nutrition and demand. In addition, French consumers consider the linkage of product qualities to the « terroir » (combined notions of a geographical location, its agricultural potential and cultural elements) and consequent knowledge of the conditions

of production and their influence on the product, are new, major events to be taken into account in our research programs. The **fourth** element is the world-wide scientific competition within animal biology and, animal production. Sequencing of genomes, wide transcriptomic, proteomic and metabolomic approaches have been able to provide a high flow of information. They require an extremely high analytic power for their outputs which allow us to explore the links and networks between genes and phenotype(s). The interest in resolving the complexity of biology has led to an increased alliance between mathematicians and biologists, using modelling as the meeting point, and has opened the way to integrative approaches (integrative biology)

PRIORITIES AND OBJECTIVES OF THE PHASE DIVISION

They belong to four domains:

- Integrative biology: functional genomics and bioinformatics, cell differentiation and modelisation
- Sustainable development of agriculture and global change
- Knowledge and acceptability of biotechnologies, animal welfare
- Meat, milk and egg qualities for human feed

The first objective is to propose to French and European political and socio-economic stakeholders, tools to maintain France and Europe among the leaders of animal productions, in terms of quantitative and qualitative animal production, but also in terms of genetic improvement of most animal species and interaction with the livestock systems. The second objective is to increase our scientific knowledge of farm animal physiology by producing original knowledge with a more integrated vision of animal biology with constitution of scientific « poles » which might associate scientific and industrial partners who share our scientific aims and models. PHASE aims (1) to increasing knowledge, from genes to their functions, on the biology and breeding of fish, birds and mammals within their farming systems, in order to better understand the fundamental mechanisms of physiological

functions which shape the phenotype and qualities of animal products, (2) to developing techniques for sustainable livestock systems to increase competitiveness of farms and producer organizations, and control quality of the products while respecting animal welfare and the environment.

To reach the objectives, the activity of PHASE staff (1250 workers including 510 scientists, 16 research units, 16 experimental units) is spread over five operational « Thematic fields »:

(1) Neurobiology, behaviour and adaptation: olfaction, cognitive process, relational behaviour, feeding behaviour and feed intake, environmental adaptation mechanisms

(2) Reproduction, embryonic and larval development, biotechnology of reproduction: male and female gametes, central and peripheral control of sexual activity, biology of embryonic development, biotechnology of reproduction, transgenesis (fish, mammals, chicken, goat, rabbit)

(3) Digestion, feeding and nutritional value of feed: regulation of ingestion and digestion, interaction between nutrition and animal health, new nutritional values of feeds, feed evaluation

(4) Dynamics of elaboration of animal tissues and related products: multiplication and differentiation of animal cells, mechanism of tissue development, metabolism, relation between protein structure and function, study of lactation, oogenesis.

(5) Conception of biotechnical livestock systems and evaluation of their sustainability: design, evaluation and modeling of livestock systems, technical, economical and social acceptability of innovations.

Studies (about 700/year) are carried out on domestic animals (beef, pig, poultry, fish) and animal models (mice, zebra fish...) and issued in numerous publications (1000/year, 45% being journal articles).

More information is available on the INRA website:

<http://www.international.inra.fr/>

and for detail information of activities in animal production :

<http://www.inra.fr/compact/nav/externe/en/departements/ecrans/17>.

MAJOR INNOVATIONS RECENTLY TRANSFERRED TO FARMS AND TO THE INDUSTRY

To illustrate the activities of the PHASE division, we proposed to present major innovations in the recent years of interest for users in the 5 areas of animal production division.

Animal behaviour and Welfare

- Producing and using welfare criteria related to animal in cattle and horses: in bovine Limousine breeds, genetic selection on docility is practised; in horses, behaviour marks have been given to some stallions for the first time in France in 2007, and mares will receive behaviour marks for future selection in one breed. Welfare criteria are used for calves, poultry and pigs (criteria used for development of European policy).

- Elaborating a multifactorial approach of welfare in farms in pigs, bovine and poultry (Welfare quality European program) in order to define a special grid to be applied in European farms.

- Development of management tools or facilities able to increase welfare in farms: housing in dairy cattle (carpets) and poultry (laying hen coops); fitness in pigs (tooth cutting, castration), which were used during the development of legislative rules.

Techniques for controlled breeding and biotechnologies

- Use of semen (liquid and/or deep-frozen semen) and embryo preservation techniques in fish, poultry and mammals: a large majority of processes used in artificial insemination and embryo transfer centres, and/or in farms come from developments in INRA units. A patent for semen preservation in horses is used by IMV (world leader of artificial insemination technologies).

- Use of in vitro biotechnologies (in vitro maturation of oocytes and in vitro fertilization) for genetic improvement in dairy and beef cattle: most of the technologies used were developed by INRA units.

- Development of a specific machine (« PulseIons ») for piloting Calcium waves around the time of fertilization in individual oocytes and embryos: patents and licensing to a start-up company (Bracer Biotech).

- Patents to use chicken embryonic stem cells for germ line transmission of transgenes.

- Use of in vitro biotechnologies for endangered species: birth of a fawn of an endangered species of deer (*Japanese Sikka*) from a common bred mother (Elaph deer) (collaboration with MNHN, National museum for nature).

- The Atlas: 'Ultrasonography and reproduction in swine' (in French, English, Spanish and Italian) sold almost 2 500 copies.

- Use, in farms, of a combination of lighting treatments and the male-effect to induce out-of-season breeding in small ruminant females, horses and poultry: half of the French goat farms use them. Use of lighting treatments in AI centres in small ruminant males: all AI centres used lighting treatments developed in PHASE labs.

- Tool for electronic detection of oestrus in ruminants: patent deposited, licensing in discussion with industrial partners.

- Use of melatonin to control out-of-season breeding in sheep: more than 300 000 implants are sold yearly all over the world.

- Use of cloning for rare and endangered individuals or breeds: one exceptional AI bull was cloned and a breed was « saved » from extinction (Aurore the last survivor of Bleu du Bazougeais bovine breed).

Engineering of animal feeding

- Development of tables of composition and nutritive value of raw materials for major farm animals (200 concentrates and by-products, 50 to 100 criteria per feed). These tables were translated in English, Spanish and Chinese and 12 000 copies were sold.

- Publication of a book on Ruminant Feeding (including 1250 forages) sold at 9 000 copies in 2007 (translation to Spanish and English in preparation).

- Recommendations on restricted feeding in ruminants, pigs, poultry, rabbits, horse and fishes, based on studies on ingestion, digestion and nutrient utilization was used to develop softwares such as: INRAtion for ruminants, translated into English, Spanish and Romanian (3 500 licences sold); Patur'in, Herb'evol and Herb'avenir for help on pasture management (several hundred users in France and Europe); INRAPorc for rationing in pigs (300 licences sold in 16 countries, 451 teaching licences); INAVI and AviSim in poultry (more than 100 licences sold to industrial partners). In fishes

optimization of feed formula to reduce incorporation of fish products in fish feeding and dumping estimates are used by feed companies. In rabbits, recommendations of fibre content and level of feeding for young rabbit health are used by rabbit producers.

- Specific husbandry schemes (use of specific AA) and additives (probiotics) to replace antibiotics in ruminants, monogastric animals and fishes were developed with private companies and used by them.

- Use of vegetable sources of nutrients (proteins and oil) for fish production was increased from 15-20% to more than 50% in the last five years.

Development of animal products designed for human feeding

- Modulation of fatty acid contents of milk and meat by specific feeds: our research has determined feeding strategies (use of Linseed) to modulate the methane emission and FA content in ruminant and pork meat and milk. These results are used by specific producers in particular to enrich animal products in omega 3 FA (Bleu Blanc Coeur, Danone, ...). A part of these programs were funded by these companies.

- Production of « Pilot animal products » with innovative compositions for studies in human nutrition (performed by AlimH division) and/or in food process (performed by CEPIA division, feed technology).

- Use of natural antioxidants in ruminant nutrition to prevent oxidation of beneficial fatty acids in meat: work with a start-up (Phytosynthèse) in the field, which uses the results of our laboratories and who grant a licence for use of the patent.

- Specific engineering of fish feeding to achieve adequate fatty acid contents of flesh.

- Participation in the drafting of recommendations for inclusion in the specifications of meat produced under quality schemes: work and expertise of PHASE scientists allow us to define typical animal products, and are used by industry to develop the specifications (i.e. the accepted rules for production) of their products under quality schemes (PDO, Protected Designation of Origin, Labels, Organic farming, etc).

- Involvement since 2006 of 10 division scientists to the AFSSA, French food safety authority group working on « Impacts of

husbandry and breeding techniques on fatty acid composition of animal products and human feeding ».

- Tools for traceability of animal products: 2 patents were registered.

- Tools for predicting meat tenderness: 1 patent with breeder organization was registered, licensing under discussion.

New livestock systems

- Development of innovative livestock systems that respect the environment: (a) 'Green Piggery' to reduce environmental effects (wastes, odours), (b) feeding systems to reduce mineral wastes, (c) management systems to retain soluble contaminants in the litter. These elements were used in developing new regulatory policies.

- Study of the consequences of innovative practices (once-a-day milking in ruminants, sequential feeding in poultry, etc), or changes in regulations (poultry cages, dates of weaning).

- Development of integrated systems of ovine production under organic farming: a research-development platform allows us to compare different management systems of animals under organic farming conditions and to test husbandry practices (antiparasitic treatments, use of concentrate feeding, management of reproduction), compatible with the specifications of organic farming.

- Evaluation of wastes from different fish rearing systems: data used by CIPA (Inter-industrial committee for aquaculture and fisheries) and ITAVI (Inter-industrial institute in charge of poultry, rabbit and fish production) for the negotiation with the Ministry of Agriculture and Sustainable Development on the French water framework directive.

CONCLUSION AND PROSPECTS

To conclude, we would like to emphasize the main evolutions of the division since recent years. Scientifically, a large number of scientists have continued to move towards a better investment in integrative biology by using transcriptomic and proteomic approaches on the agronomic species, in spite of difficulties in the development of specific tools at the beginning of the period. These approaches, combined with classical methods for the characterization of phenotypes, have allowed PHASE to keep his place in the

worldwide competition for physiological explanations of the variability of adult traits.

The implication in functional genomics was also improved, but this was more an increase in the use of model animals (mice and fish) than the development of new and specific genetically-modified agricultural models. For the latter, we still need to develop efficient tools for easy genetic engineering, a domain in which we are active and in which our teams are competent, but where the scientific challenges to be overcome are numerous and difficult. The production of these tools for our domestic species will open the door to easily obtainable genetically modified animals.

A continuous investment was also made in modelling approaches, from gene networks to livestock systems, passing from cells to tissues, organs and animals. This allowed the development of fruitful cooperation with scientists of a completely different culture (mathematicians) than that existing in PHASE division. The scientific development towards the exploration of sustainable systems of production was more difficult because it needed a more profound change in mentalities and, for a part of the PHASE scientists, a move far from their immediate scientific fields.

Scientific investments were made with the idea that PHASE should propose innovations, know-how and explanations linked to livestock productions, not only to farmers but now to all of society. PHASE division should continue to support the 'reversible continuum' between basic science which provides original and competitive results and explanations, and applied science which provides innovations and know-how.

Regarding experimental facilities and units, the objectives were to modernize them ready for a future European accreditation. Units were merged in various sites in order to rationalize and increase the efficiency of the systems and to constitute new units under a renewed management.

The budgetary management of the division was oriented in three main directions in order to stabilize the units but stimulate some area of research:

- Maintain a minimum direct and non-scientifically orientated budget for units to allow them to develop their own policy

- Reserve an increasing part of the budget for incitation funds dedicated to the objectives proposed in the strategic agenda, and allowing recently-recruited scientists (especially young ones) to develop new and innovative programs

- Specific activities open to outside partners to build the initial elements of new programs to be submitted later to ANR (national research agency which is founding research programmes).

In the next strategic agenda, PHASE division priorities will firstly to continue the investment in integrative biology and to develop, in close association with GA division (Animal Genetics), a large program of high-output phenotyping. This would be done under GA responsibility for phenotype characterization of agricultural animals, with a strong implication of the PHASE division for definition of traits and use of experimental units.

The second priority is the proposition of a very large program regarding the ecological-nutritional imprinting of animal products, and its consequences on innovative and sustainable systems of production. Everyone now recognizes that we should adapt our production livestock systems to better integration in their natural environment, thus developing ecologically intensive farming systems, but only a few scientists have reached the objective of proposing systems which can produce under such constraints. One way to change the systems is to provide consumers with an exact and exhaustive indication of the origin, conditions of production and qualities of the products they are consuming.

Finally, PHASE division will also continue to support essential programs such as modelling approaches. PHASE will also re-organize research and experimental units and raise facilities to a high standard which will enable them to be used by European partners.

REFERENCES

*** <http://www.international.inra.fr/>

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