Biotechnology and Animal Production

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ABSTRACT

A review of biotechnology in animal production has been made. The objectives were to review the development and use of animal biotechnology, measures of safety/prevention of adverse effects resulting there-from and recommend measures needed for their safe development and use. The review reveals that classical quantitative genetic, reproduction and vaccine production methods are very developed and used worldwide for genetic improvement and health of livestock to meet food needs. The results were increased food production and genetic erosion resulting from adoption of fewer breeds. To guard against consequences of genetic erosion, *ex-situ* and *in-situ* conservation methods were used. Modern biotechnology in animal improvement is still at embryonic stage and shows signs of public concern. National regulations governing animal breeding health and conservation of genetic resources neglect endangered breeds and modern biotechnology ("genetic modification") which, however, is not yet practiced. It is recommended that transgenesis be directed to areas not easily handled by classical breeding methods (which are still to have needed application in Africa), conservation/exploitation and import/export measures on livestock be updated to include endangered and endemic genetic resources, and modern biotechnology. More serious efforts should be made in the collection and maintenance of breeds at risk. To enable benefit from modern biotechnology, frameworks for its safe development and use, given public concern, should be put in place.

Key words: *selection, crossbreeding, artificial insemination, mutagenesis, genetic engineering*

RESUME

Un bilan sur la biotechnologie animale a été fait. L'objectif était de faire le point sur le développement et l'utilisation de la biotechnologie animale, les risques y associés, les mesures de sécurité et de prévention des risques. Ce bilan montre que les méthodes classiques de la génétique quantitative, de la reproduction et de la production des vaccins sont très développées et utilisées dans le monde entier pour l'amélioration génétique et en santé animale en vue de satisfaire les besoins alimentaires. Les résultats obtenus portaient sur l'augmentation de la production alimentaire et l'érosion génétique. Les méthodes de conservation *in situ* et *ex-situ* étaient utilisées comme moyens de protection contre les conséquences de l'érosion génétique. La biotechnologie animale moderne est encore au stade embryonnaire et fait l'objet d'une préoccupation de la communauté nationale et internationale. La réglementation en matière de l'élevage, de la santé et de la conservation des ressources génétiques animales néglige les races en péril et la biotechnologie moderne. Il est recommandé que l'utilisation de la transgénèse soit orientée vers les domaines où les méthodes classiques d'amélioration génétique sont difficilement applicables et que les races en péril et la biotechnologie moderne soient prises en compte dans la réactualisation des mesures d'exportation/exploitation et d'importation/exportation. Pour tirer profit de la biotechnologie moderne, un cadre de biosécurité devra être élaboré.

Mots clés : *sélection, croisement, insémination artificielle, mutagénèse, gène génétique*

1. Introduction

Member States of African Agency for Biotechnology have embraced the development and use of biotechnology defined as "...technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use". In its article 19 (3), the Convention on Biological Diversity (CBD) stipulates the need by parties for modalities of a protocol setting out "appropriate procedures of safety/prevention of adverse effects resetting therefrom and recommend measures needed foir their safe development and us, advance informed agreement, in the field of safe transfer, handling and use of any Living Modified Organisms(LMOs) resulting from biotechnology that may have adverse effect on the conservation and sustainable use of biological diversity". While man has biotechnologically produced and used LMOs without the caution expressed by this article, the caution became necessary when he produced in the 1970s LMOs with *novel traits* defined as "organisms resulting from genetic modification with make-up unlikely to occur in nature" (UNEP, 1995). Such organisms are produced using non-conventional and non-traditional breeding/mating methods. If a country must benefit from biotechnology she must first of all implement article 19 of the Convention on Biological Diversity. This is imperative if "safety" and prevention/control of "adverse effects" must be guaranteed when use is made of LMOs in general and LMOs with novel traits in particular.

The objectives of this paper include:

i. To review the development and use of animal biotechnology,
ii. To review the measures of safety and prevention of adverse effects concerning the use of animal biotechnology, and
iii. To recommend measures needed for safe development and use of animal biotechnology.

2. International Situation of animal biotechnology

The situation of animal biotechnology is treated under genetics, reproduction, nutrition and health.

2.1 Genetics

Livestock biotechnologies aimed at genetic improvement of farm animals for increased meat, milk, eggs, disease and stress resistance, etc, have used artificial control of sexual reproduction of entire organisms within species (Falconer, 1981). The techniques have been artificial selection, crossbreeding, artificial insemination and mutagenesis. These methods are generally characterized by randomness and long expectation time to achieve desired results. The selection for/against a given trait or crossbreeding for a given trait modify the resulting organism genetically as the gene frequencies of targeted traits may be increased/decreased as desired. While such methods have been intensely used in the North (Falconer, 1981), they are relatively recent introductions and applications in the South (Mandon, 1957; Lhoste, 1977; Plasse, 1979; Mbah et al, 1987; Tawah and Mbah, 1989; Tawah et al, 1993; Tawah et al, 1994).

However, the resulting modified traits are not novel for the species. In the absence of public rejection/ debate of the techniques used and results obtained, there has been wide-spread adoption of the technologies resulting in desirable increases in food (animal products) and undesirable levels of genetic erosion, exposure to diseases, pests and environmental stresses.

Modern livestock biotechnologies operate at *cellular* and *molecular* levels. At cellular level, randomness is less as changes are more easily identified. The species barrier is broken. At molecular level, genetic engineering (variously known as recombinant DNA, gene manipulation, gene cloning or new genetics) is applied (Cohen, 1975). Figure 1 (adapted from Cohen, 1975) illustrates the genetic engineering procedure.

Four essential steps are involved:

1. Method for cleaving and annealing DNA molecules from different sources (e.g endonuclease, Eco R1 and DNA ligase,respectively),
2. Suitable gene/fragment carrier (vector) that can replicate itself as well as the foreign DNA fragment "attached" to it (e.g. plasmid),
3. Means of introducing the recombinant molecule (chimera) into a functional bacterial (host) cell (transformation), and
4. Method of selection of clone (s) of recipient cells having the chimera from a large population of cells.

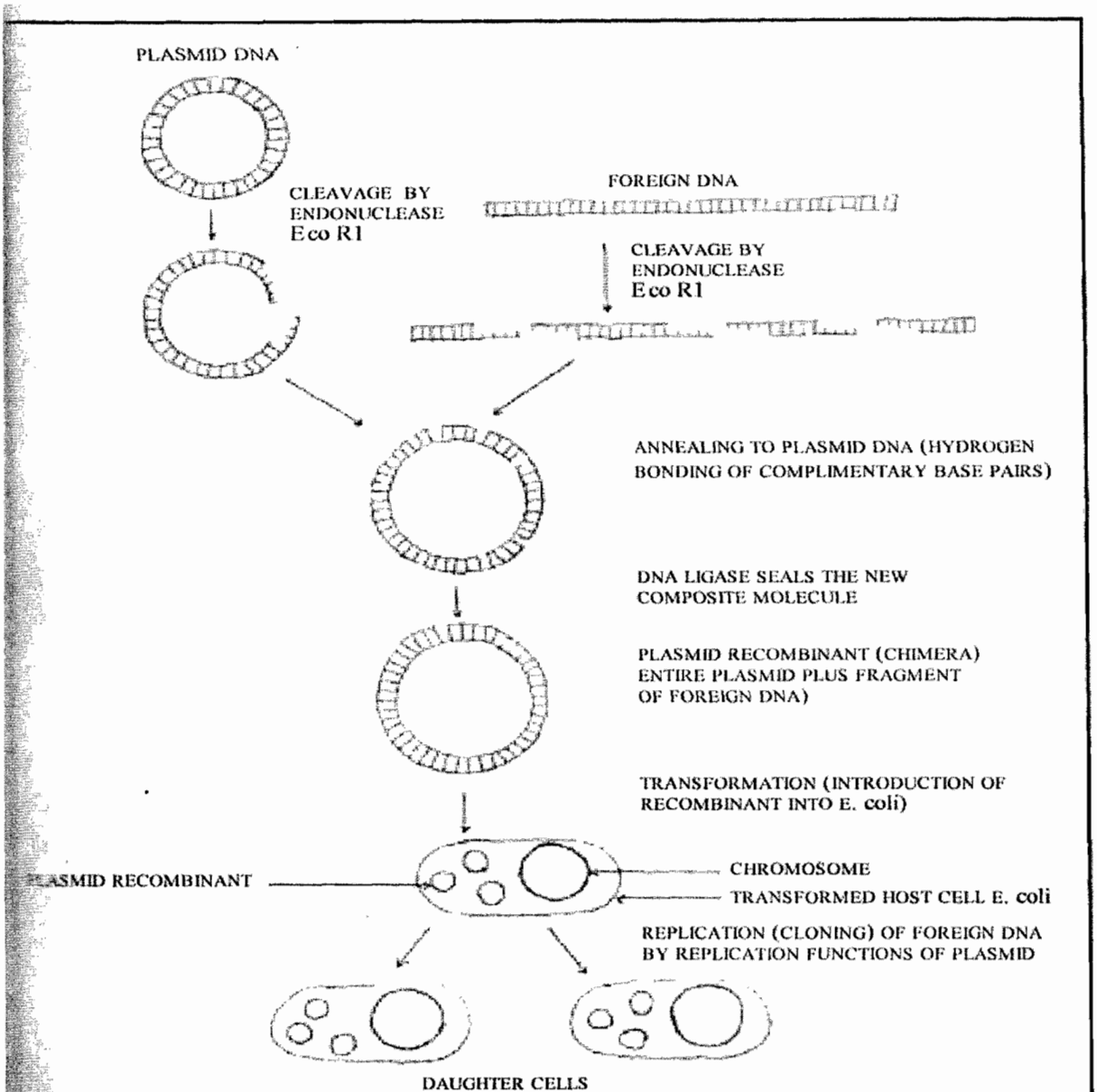

Fig. 1: GENE MANIPULATION (BIOCHEMICAL AND BIOLOGICAL MANIPULATIONS RESULTING FROM DISCOVERIES IN THE MID 60s AND EARLY 70s [COHEN, 1975])

The transformed cells (bacteria: *E. coli*) in the figure expressed:

1. The typical antibiotic resistance of the plasmid , and
2. The trait of the foreign DNA.

Hence, the transformed cells ("clones") now had *novel trait(s).*

Next, similarly, a combination of DNA from the plasmid of another bacterium,*Staphylococcus aureus* with that of the original *E. coli*:

1. Cleavage of mixed plasmids with Eco Rl endonuclease,
2. Annealing with ligase,
3. Transformation of *E. coli*, and
4. Isolation of bacteria *(E.coli)* expressing penicillin resistence (*S.aureus* plasmid) and tetracycline resistance of *E. coli* plasmid. Double resistant cells contained *new* species of *S.aureus* plasmid DNA as well as characteristics of *E.coli* plasmid (PSC 101).

"The replication and expression in *E. coli* of genes derived from an organism ordinarily quite unable to exchange genes with *E. coli* represented a breach in the barriers that normally separate biological species". This was between bacterial species. What about

between bacterial and animal species? Genes coding for ribosomal proteins in the toad, *Xenopus laevis* were similarly introduced into the *E. coli* plasmid, PSC 101. Transformed cells expressed antibiotic resistance as well as being found to contain mucleotide sequence homology with DNA directly isolated from the toad. The "animal cell genes were indeed reproducing themselves generation after generation of bacteria by means of the plasmid's replication function".

Subsequently, the method was used in several laboratories to clone bacterial and animal cell DNA from diverse sources. *It is now possible to isolate groups of genes expressing themselves at the same time in the development of an animal.* The ground had been set for "introducing new genetic information into plant or animal cells" from various sources making it possible for exchange of genetic material between virtually any given combination of species. The leading investigators in the field recognized the potential danger in the destruction of the natural genetic barrier between biological species and initiated debate in 1974 (Grobstein, 1977) on gene manipulation experiments. The debate led to the establishment of physical and biological containment based on the established guidelines (Grobstein, 1977).

At the level of animal to animal, the procedure in Fig 1 is adapted as follows (Smith, 1996):

1. Identification/construction of foreign gene,
2. Microinjection of identified DNA (gene) into pronucleus of a fertilized egg,
3. Implantation of resulting recombinant (chimera) eggs (cells) into surrogate mothers,
4. Development of the embryo to term,
5. Proving that the foreign DNA has been stably and heritably incorporated into the DNA of at least some of the newborn offspring, and
6. Demonstrating that the gene expresses itself in the new environment (recombinant).

Using this procedure, a *rat* gene (for growth hormone) was inserted into the *mouse* genome. It expressed itself, producing progeny that were much larger ("super mouse") than the parents (Nicholl, 1994). These were the first transgenic animals (i.e. animals with novel traits). Since then, transgenic sheep, cows, goats, pigs, rabbits, chicken, fish (salmon, catfish, zebrafish, crustaceans) have been produced (Table 1).

While there is great potential for meat production, there is no wide acceptance of the technology given the great controversy generated by it. The concerns are at 3 levels (NRC, 2002) :

Table 1: State of transgenic technology in animal production*

Organism	Transfection	Viral Vectors	Transposon	Embryonic stem cells	Nuclear Transfer
Mouse	4+	2	1	4+	2
Cow	3	1	-	-	2
Sheep	3	-	-	-	2
Goat	3	-	-	-	2
Pig	3	-	-	-	2
Rabbit	3	-	-	1	-
Chicken	1	2	1	-	-
Salmon (Atlantic)	3	-	-	-	-
Catfish	2	-	-	-	-
Tilapia	3	-	-	-	-
Zebrafish	1	-	-	1	1
Crustaceans	1	1	-	-	-
Molluscs	1	1	-	-	-

*Adapted from NRC, 2002
1 = proof of concept, 2= routine experimental use, 3 = commercialisation sought, 4 = widespread production (+ = experimental use).

Table 2 : Risk factors for genetically modified animals*

Animal	Capacity to become untamed	Possibility of escape from captivity	Mobility	Community Disruptions	Level of Risk
Fish	H	H	H	Ma	H
Mice & rats	H	H	H	Ma	
Cat	H	H	Mo	Ma	
Pig	H	Mo	L	Ma	
Goat	H	Mo	Mo	S	
Horse	H	Mo	H	F	
Rabbit	H	Mo	Mo	F	
Mink	H	H	Mo	-	
Dog	Mo	Mo	Mo	F	
Chicken	L	Mo	Mo	-	
Sheep	L	L	L	F	
Cattle	L	L	L	-	L

* Adapted from NRC, 2002
H = high, Ma = Many, Mo = Moderate, F = few, S = some, - none, ⟶ reducing risk

(a) Food safety (involving products from beef/dairy cattle, sheep/goats, poultry and eggs, pigs, rabbits, fishes, etc) : New/introduced genes could lead to new proteins which may have any of the following effects:

- allergenicity,
- bioactivity (of molecules enhancing growth, etc), and
- toxicity.

(b) Animal health : Ruminants (cattle, sheep and goats) produced through *in vitro* culture or nuclear transfer methods (containing or not containing transgene(s)) lead to :

- higher birth weights, and
- longer gestation lengths

than for calves/lambs from artificial insemination. Large offspring syndrome (LOS) is frequent among cattle from *in vitro* methods leading to calving problems.

(c) Environment effects : *risk* of transgenic animal entering the natural environment through *release* or *escape* (Table 2).

The transgene could spread through *vertical* (reproduction with wild relative) or *horizontal* transmission by vectors.

Efficiency of the methods : Extremely inefficient being only 0 – 4% in cattle, sheep, goats, pigs. Mortality varies from 80 to 90% during early development. Furthermore, survivors (many) show improper expression of inserted gene. They also have anatomical, physiological and behavioural abnormalities.

The International Livestock Research Institute (ILRI) conducts research to identify, develop and test genetic markers and genes controlling disease resistance, etc, (CGIAR, 1998). Evidently, gene transfer techniques in animals still need improvement of efficiency, isolation and characterisation of genes of interest in breeding, isolation and characterization of acceptable regulation elements (Brem and Wagner, 2003).

2.2 Recombinantly produced hormones (BST, PST)

2.2.1 Bovine growth hormone, bovine somatotropin (BST): The gene was isolated in the 1980s (Smith, 1996) and inserted into bacterial cells for massive production of BST. Injection of lactating cows with 30 mg of it increases milk yield by 10-30% (Murphy et al, 1994; Smith, 1996, Badinand and Lahlou-Kassi, 1996). Increases are more dramatic in zebu cattle (Badinand and Lahlou-Kassi, 1996) and production levels can be maintained by injections every 2-4 weeks. Using primigravid ewes, BST (non recombinant) was shown to reduce body fat by 17% (total body fat) to 28% (sub-cutaneous fat) (Stelwagen

et al, 1994).

2.2.2. Pig Somatotropin (PST): Similar studies with pig somatotropin showed that body fat can be reduced by 80% while increasing feed efficiency by 20% (Smith, 1996).

Despite the apparent promise in increase in quantity and quality of milk and meat and approval by the United States Food and Drug Administration (USFDA), there is still resistance to adoption particularly in Europe. There is evidence, however, that cows treated with BST have increased mastitis and pigs transgenic for PST have joint and skeletal problems (Smith, 1996).

2.3 Animal Health (Vaccines and Diagnostics)

2.3.1 Vaccines are preparations from *dead* microorganisms (or parts thereof), or *living* attenuated or *weakened* microbes administered to animals to stimulate immunity to infection by living, unattenuated or unweakened organisms. The foreign organism carries on its surface an *antigen* (protein in general) which upon contact with the host system *stimulates* a counter response, an *antibody* which constitutes *immunity* against a disease that can result from the infection. This classical method of vaccine production is still very much the rule given that modern biotechnology has not yet had a break-through in the domain. ILRI conducts research to identify antigens of livestock pathogens aimed at vaccine development (ILRI, 1998). Recombinant DNA methods of vaccine production are available (and some recombinant vaccines have already been produced).

2.3.2 Diagnostics now benefit more from modern biotechnology (Table 3):

Production and use of monoclonal antibodies (immortalization and stabilization of antibody producing cells results in secreted antibodies being *always* the *same* from a given cell line and can be characterized/assessed for different uses). Immunoassays (use of monochonal antibodies), DNA probes (hybridization assays) based on hybridization of DNA

Table 3: Transgenic animals as producers of pharmaceutical products*

Species	Yield(g/yr of raw protein)	Products being developed
Chicken	250	Monoclonal antibodies Lysozyome Growth hormone Insulin Human serum albumin
Rabbit	20	Calcitonin Superoxide dismutase Erythropoietin Growth hormone IL-2 a -glucosidase
Goat	4000	Antithrombin III Tissue plasminogen activator Monoclonal antibodies α - Antrypsin Growth hormone
Sheep	2500	α - Antrypsin Factor VIII Factor IX Fibrimogen
Cow	80 000	Human serum albumin Lactoferrin α - Lactalbumin

*NRC, 2002

sequences of DNA and RNA are used in animal disease diagnosis. Diagnostic kits are available (particularly for fertility hormones). Here, too, ILRI carries out research aimed at developing tests for improved diagnosis.

2.4 Animal Feedstuffs

Traditional biotechnology in this domain includes forage selection and crossbreeding as applied to plant breeding (see crop production and protection paper of the project). Silage ("fermented fodder") techniques are widely used in conserving cattle feed. Modern biotechnology aimed at crop plants may apply to forage crops (ILRI is also working in the domain).

2.5 Reproduction (artificial insemination, multiple ovulation and embryo transfer, embryonic micro-manipulation). These technologies are usually tools of genetic improvement.

2.5.1 Artificial insemination (A.I.)

The first generation of reproduction biotechnologies, A.I, the most used worldwide, involves artificial mating of selected males to several females. Male fertility is greatly mulitplied. While all classes of livestock are involved (Tanturier et al, 1996; Lofti et al, 1996; Diop et al, 1996; Ouedraogo et al, 1996), its greatest use is found in cattle (beef, dairy). However, in Africa, few countries (Kenya, South Africa, Moroco) have artificial insemination centres (Lofti et al, 1996).

2.5.2 Multiple ovulation and embryo transfer (MOET)

Constituting the second generation of reproduction biotechnologies, it involves super-ovulation of superior females (donors), artificially inseminating them and transferring of fertilized eggs into surrogate mothers (recipients). Female fertility is multiplied. The technology is still very undeveloped, particularly in Africa.

2.5.3 Embryonic micro-manipulation

Manipulation of embryos includes embryo splitting (EMS) (increase fertility of superior stock), embryo sexing, use of cytogenetic, immunologic and chromosome techniques), *in vitro* fertilization, egg modification through the introduction of agents carrying desired genes and cloning (nuclear transfer). Embryo splitting and nuclear transfer (BNT) methods used since the 80s in dairy cattle. About 1,400 cows registered by the Holstein Association in the U.S. They successfully calved and were milked. Somatic nuclear transfer (SNT) was perfected in the production of Dolly (now dead after 6 years).

The techniques are not yet of wide commercial use despite the fact that no complains have been raised. While other embryonic micro-manipulation techniques appeared to be accepted by the general public, cloning was met with rapid and inhibitory public reaction.

3. Conservation of genetic resources

Applications of genetics (2.1) and reproduction technologies (2.5) have promoted the development and use (adoption) of few species and few breeds within species for production of desired products (meat, milk, eggs, etc). This has led to biodiversity loss (species/breed extinction and genetic erosion within breed) (FAO, 1995). "More than 30% of all remaining animal genetic resources are now classified either on the critical-maintained, endangered or endangered-maintained list (FAO, 1995). To combat the continuing trend towards biodiversity loss, the FAO (1995) has set up "The Global Early Warning System for Animal Genetic Resources".

Drawing from the "very small number of engineered mutations" found useful in improving crop production and the greater complexity of animals (about 100,000 genes in the DNA of each) which, through genotype-environment interaction, produce adaptations called for by each environment and human needs, the FAO (1995) states that the "technology to achieve artificially the vast array of changes in genetic make-up which could be supplied by currently existing and readily available genetic resources does not exist now and may well not exist a century from now".

Worldwide, *ex situ* conservation (cryo-preservation of semen, ova, embryos or tissues from which animals can be regenerated) technologies exist but the cost is prohibitive. Given the cost, preservation of live animal samples out of their normal habitat/ production environment is not popular. Nevertheless African countries need to give special attention to the conservation and use of endemic genetic resources (Hanotte et al., 2000; Hanotte et al, 2002). Gene manipulation techniques as discussed above (2.1) do not serve conservation objectives (note de-

struction of biological barriers among species) but can be useful tools for genetic improvement of livestock. At the moment, regeneration of whole animals/organisms from *isolated* DNA is not technically possible (FAO, 1995).

4. Cameroon situation of biotechnology

4.1 Genetics

Traditional/classical genetic improvement techniques discussed above (2.1) have seen their introduction and application in Cameroon (Mandon, 1957; Lhoste, 1977; Mbah et al, 1987, Tawah and Mbah, 1989; Tawah et al, 1993, Tawah et al, 1994). Clearly, emphasis has been on genetic improvement of cattle for yields of beef and milk as well as disease resistance (Mbah, 1982; Mbah, 1984). Less attention has been given to poultry, pigs, sheep and goats, etc. Where genetic improvement was through crossbreeding imports of frozen semen from the North for artificial insemination were the rule (Mbah et al, 1987). Again, more imports were made of bovine semen while other species imports were live animals (adults, day-old chicks). While having the same characteristics and results as elsewhere (2.1), due to their recent introduction and high cost, the techniques have been less widely adopted outside government structures (research stations, etc.). However, crossbreeding cattle for beef and milk appear to be gaining ground as the private sector is now involved (SOGELAIT, Ngaoundere; Bamenda Dairy Cooperative Society and Tadu Dairy Cooperative Society) with imports of semen from the North). The Tadu Dairy Cooperative Society (TDCS) is very active in the area (TDCS, 1998). The Heifer Project International (HPI), an American NGO working with smallholder livestock farmers (about 4000 in the Northwest, West and Southwest Provinces), is also very involved.

Given the yet low level of application of genetic improvement techniques, diversity/variability is still abundant among local species/breeds (Tawah et al, 1993; Mafeni et al, 1997). To conserve this diversity/variability, the government has enacted two (2) texts, namely:

1. Decree no. 76/420 of 14 September 1976 to control animal husbandry, cattle movement and exploitation. The stated purpose is to preserve certain cattle breeds through:

   i. creation of special zones, "breed cradles", within which animal production activities are strictly controlled to achieve specific objective(s),
   ii. regulation of commercialization of males and females of targeted breed(s), and
   iii. other measures that present or develop a given cattle breed.

1. Order no 013/MINEPIA of 31 May 1994 to create the cradle of the Gudali (Ngaoundere) breed of cattle with the stated purpose of preserving the breed (for meat potential in particular) through protection (isolation) from breeding with other breeds. No other breed is allowed into Vina Division except for research purposes. Purity of the breed is controlled while a "Herd Book" is created (Station Zootechnique) for registration of individual performance. A Gudali Breed Association is still to be formed by breeders concerned. It is important to note that the endemic and trypsanotolerant breed, Namchi, and other endangered breeds, Kapsiki, Bakosi/Bakweri, Black belley, do not benefit from these texts yet. No genebanks exist. However, some collections (particularly of breeds at risk) exist on agricultural Research Stations (Wakwa, Yagoua, Nkolbisson).

4.2 Reproduction (A.I, MOET)

Of the 3 or 4 generations of reproduction biotechnologies, two (2) are used but at different stages of development.

4.2.1 Artificial insemination

The first generation of the biotechnologies of reproduction, A.I has wider application nationally (Mbah et al, unpublished data). It is practised by research stations, three (3) cattle (dairy) cooperatives and the HPI which import frozen semen from Europe or USA. The TDCS is the most involved in the domain considering its contracting capacity (TDCS, 1998).

4.2.2 Multiple ovulation and embryo transfer

This second generation of the technologies is still at the level of the research station. The purpose of research on MOET is to refine the technology which will eventually be used to conserve the breeds at risk (Namchi, Kaptsiki, Bakosi/Bakweri, Black belley) through increased reproduction (i.e. multiplication).

4.3 Feedstuffs

Outside pastures/forages, compounded animal

feedstuffs are regulated by Order no. 103/MINEL of 13 October 1978 as amended by Order no.00019/ MINEL of 9 may 1979. These orders fix the modalities for opening of feed production houses or commercialisation of products destined for feeding domestic animals. The quality of feed is controlled by requiring that:

i. packaging must indicate conservation life/expiration date, etc, composition, and
ii. if samples (analyses) show presence of elements dangerous for health, foreign bodies, etc, feedstuffs are seized and destroyed.

The major feed compounding business is the Cameroon Feedstuffs and Transformation Company (STPC) in French). This is followed by feedmills on Agricultural Research Stations which manufacture salt-licks as well. Trace elements and vitamins ("mineral premix") are imported (to be used as components of compounded feedstuffs) while major energy and protein sources are locally available (from agro-industrial complexes such as Maiscam, SODECOTON, SEMRY, UNVDA, CDC, SOCAPALM, etc). Crop residues (groundnut haulms, sorghum/millet/rice straws, etc.) are important from the savanna through the sudan to the sahel zones.

4.4 Animal health measures

The policy on animal health has two essential components: "control" of diseases and vaccine production.

4.4.1. Regulations (laws, decrees, orders, etc)

Of all the texts on animal health, law no.74/13 of 16 July 1974 to name and regulate zoo-sanitary diseases of cattle reputed to be contagious and requiring obligatory declaration is the most important. The purpose of the law is to prevent disease by:

i. drawing attention to the most contagious diseases by listing them (tuberculosis, rinderpest, foot-and-mouth disease, African swine fever, etc),
ii. requiring declaration to administrative official and obligatory isolation of sick animals, and
iii. requiring destruction of carcasses (and dead animals).

Importantly, the law provides for sanitary police at the frontiers with special measures for imports and exports of animals or parts thereof as follows:

1. **Point of entry (import(s), examination of :**
   i. all living animals (domestic and wild), and
   ii. all products of animal origin.

All imports of living animals must be accompanied by a health certificate by the competent authority in the country of origin. Breeding stock (mammals, birds, hatching eggs or semen) importation is authorized but there must be prior sanitary guarantees. Sick animals may be killed on the spot or at the nearest abattoir depending on the disease or quarantined or returned. Only "clean" meats are imported.

1. **Point of export:**
   i. all animals of all species for export (land, air, sea, etc.) are subjected to veterinary visit and quarantine where necessary, and
   ii. they must have health certificates in due form.

Common measures for export/import: movement of animals across the frontier (transhumance) is authorized following conformity with requirements agreed upon by Cameroon and the frontier countries. Penalties are prescribed for infractions.

Two other texts deal with internal control of diseases: Decree no. 86/755 of 24 June 1986 to modify decree no. 76/420 of 14 September 1976 to control animal husbandry, movement and exploitation and circular no. 012/MINEPIA/85/DSV of 14 March 1984 on restocking piggeries decimated by African Swine Fever (ASF). The former aims at maintenance of good health through prevention of the spread of disease while the latter prescribes control/ prevention measures against African Swine Fever.

Furthermore, two other texts regulate sanitary inspection. Law no. 75/13 of 8 December 1975 gives a list of diseases requiring inspection while stipulating what must be declared (all sick or suspected (sick) animals and all products derived from animals/fish susceptible to propagation of germs/disease agents). On the other hand, decree no. 86/711 of 14 June 1986 concerned with sanitary aspects of slaughter animals, meats and fisheries products, storage/conservation, etc, of products of animal origin requires all food products of animal origin (dairy, eggs, meats, fish, etc) and their derivatives to conform with international code (export/import).

Recently, law no. 2003/006 was enacted by parliament to regulate modern biotechnology in Cameroon.

4.4.2 Vaccine Production

While vaccine production still uses traditional methods (2.3.1), it is important to note that the National Veterinary Laboratory (LANAVET) at Garoua produces vaccines of good quality to cover major diseases of all livestock species important to Cameroon and the entire West and Central African region. Research done at the Institute of Agriçultural Research for Development (Wakwa Regional Centre and associated Centres/Stations) supports some of the vaccine production effort.

It is worth noting that despite all these measures in favour of animal health, out-breaks of rinderpest and ASF were reported in the 1980s. Evidently, strict implementation/enforcement of the measures is not without faults. The out-breaks were attributed to imports of infected pig (s)/products (ASF) and trans-frontier movement of infected cattle (rinderpest).

5. Conclusion (s)

A review has been made of biotechnology applications and related biosafety measures in and out of Cameroon's livestock sector. Internationally, genetic and reproduction biotechnologies have gone beyond the classical to include gene manipulation or the new genetics. With these modern biotechnologies, livestock resulting from inter-species exchange of genes, transgenics, expressing novel traits have been created. Intensive and extensive debates on the potential dangers resulting have led to establishment of guidelines, and physical and biological containment to regulate the gene manipulations. Classical genetic improvement technologies, selection and crossbreeding, are used nationally with more emphasis on beef and dairy cattle than on other livestock species. The first two generations of reproduction biotechnologies, artificial insemination (A.I) and multiple ovulation and embryo transfer (MOET) are used with A.I already adopted by users while MOET is still being experimented upon. Characteristically, both genetic and reproduction biotechnologies have tended to promote certain species/breeds at the detriment of others. Organisms with novel traits (genetically modified organisms with novel traits) have neither been produced nor used. The technologies used did not break the biological barriers that prevent species from exchanging genes (i.e recombinant DNA technology was not used). While some breeds are at risk (critical numbers), diversity still exists even among the most promoted breed. Government has taken conservation measures in favour of some breeds, not at numerical risk but has ignored endemic breeds with critical numbers. No gene banks exist but some ex-situ collections are on experiment stations. Regulations governing import/ export of animals or derived products have been set up to control or prevent animal disease. Similar measures have been set up to control/prevent diseases and animal movement within the country. Understandably, none of the regulations/ measures concerns any aspect of genetically modified/living modified organisms with novel traits.

6. Recommendations

The following recommendations result from the preceding conclusions:

1. Regulations governing import/export of animals and related products should be updated or elaborated to handle organisms with novel traits;

2. Regulations/guidelines governing biotechnology (particularly gene manipulations) research, development and use should be set up to allow each country benefit from its vast potential;

3. Conservation and exploitation measures should be updated in the spirit of the convention on Biological Diversity and extended to include breeds at numerical risk;

4. Research and development work should be extended to include all breeds (particularly endemic ones) in each country;

5. More serious efforts (including capacity building and information exchange) should be made in collection and maintenance of breeds at risk;

6.An efficient mechanism to monitor and enforce results of recommendations 1to 3 should be put in place.

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Loi no. 2003/006 du 21 Avril portant régime de sécurité en matière de biotechnologie moderne au