Sustainable rabbit breeding and genetic improvement programs achieved in developing countries

*M.H. Khalil**, G. Bolet**

Introduction

The rabbit meat production can represent for developing or less developed countries a valuable source of proteins given the prolificacy of this species and its capacity to use local feedstuffs or agro-industrial by-products. To reduce the animal protein shortage of the population and promote new agricultural productions, some of these countries decided to develop this production, in small or medium-scale units. The failure of some past projects, based on the importation of exotic breeds (Lukefahr 2004; Oseni 2008a) led them to consider more sustainable projects. This paper will review and analyze some of these projects, focusing on their genetical aspects, namely: (1) genetic improvement programs (2) estimation of selection responses; (3) direct and maternal heterotic effects obtained from crossbreeding; (4) attempts to identify specific genetic markers. However, it is necessary to remember that other aspects such as management, sanitary conditions, feedstuff availability are as well important (see for example Lukefahr 2004; Samkol and Lukefahr 2008).

Sustainable genetic improvement programs in developing countries

A sustainable genetic improvement program must take into account economical, sociological and ecological aspects. From a genetic point of view, the promoters must answer, among others, the following questions:

- Are there local genetic resources? Were they evaluated? Are they of interest and/or endangered?
- What kind of production and producers do they encourage: small, medium or large-scale units? Are the farmers able to buy initial and replacement bucks and does?
- Is there a technical training to help farmers? Is there a political will to support this production?
- What is the outlet for rabbit meat: familial consumption, small markets, restaurants, large scale distribution channels,…?

Genetic improvement is mainly based on selection and/or crossbreeding. Selection allows to accumulative additive genetic progress, while the main interest of the crossbreeding between breeds or strains is to profit from their complementarity and the effect of heterosis (Bidanel 1992). In Europe, specialized strains are selected to produce F1 females, which are crossed with a sire of another strain to produce terminal product. This solution has the advantage of exploiting at each generation the entirety of the effect of heterosis (direct and maternal), but it requires a complex scheme, based on the maintenance and selection of the pure stocks and the multiplication and diffusion of the crossbred females. It is the reason why these turnkey

[*]Faculty of Agriculture, Benha University, Moshtohor, 13736, Tukh, Qalubia, Egypt maherhkhalil@yahoo.com
**INRA, UR631 Station d'amélioration génétique des animaux, F-31320 Castanet-Tolosan, France gerard.bolet@toulouse.inra.fr

programs are rarely used in developing countries, except in some large scale private units. They need an important investment and create a technical and economical dependence which does not usually fit the social and economical environment.

Another solution is to create a synthetic line by crossing females of a local population or breed, well adapted to the environment, with imported males or semen from a selected strain to produce a F1 population ; it will be bred without selection during few generations, avoiding consanguinity, and constitute a nucleus submitted to selection. This solution makes possible to provide farmers with improved animals, while ensuring their independence. It lets to the farmers the faculty to adapt their strategy of renewal of their herd to their possibilities: they can practise self-replacement without loss of the genetic level, buy males or the two sexes to the nucleus, permanently or punctually to profit from the genetic progress carried out. It does not exclude the terminal crossbreeding with a male. Table 1 summarizes the main characteristics of such programs in which one of the authors is involved or which were recently described in the literature.

Another solution is to select pure breeds, either from local populations, either imported. This solution is less and less used, for different reasons: local populations performances are usually very low, even if they are well adapted, imported breeds often do not adapt to poor environments and, in both cases, complementarity and heterosis are not exploited.

Asia.

In Saudi Arabia, a national project of rabbit production was established to detect the possibilities of producing meat rabbit under industrialized and hot conditions (Khalil et al, 2002, 2005). For this reason, special emphases were paid to construct a genetic improvement programme to develop new lines of meat rabbits convenient for this developing hot country. Accordingly, V-line rabbits were imported in 2000 from the university of Valencia (Spain) and were crossed with desert Saudi rabbits (Gabali). This program was based on an evidence stating that V-line rabbits and their crosses could produce efficiently under hot climatic conditions (Khalil *et al.* 2002; Al-Sobayil and Khalil 2002). From this program, two synthetic lines (Saudi-2 as a maternal line with the structure of ((¾V¼S)2)2 and Saudi-3 as a paternal line with the structure of ((¾S¼V)2)2) were developed from crossing Saudi Gabali with V-line rabbits, both selected for litter weight at weaning and individual weight at 84 d (Table 1). Details concerning the development of these new lines were presented by Khalil *et al.* (2002, 2005) and Al-Saef *et al.* (2008).

North Africa.

In Algeria, an attempt to introduce selected strains and develop rabbit meat production (between 1985 and 1988) failed because of many factors, among which the lack of knowledge of the animal, the absence of an adapted industrial feedstuff, the absence of a prophylactic program. Afterwards, the strategy of development of this species was based on the use and upgrading of local populations but Kadi *et al.* (2008) underlined the weakness of this industry. Thus, since 1990, the Institut Technique de l'Elevage (ITELV) and some universities, especially that of Tizi Ouzou, set up programs of characterization of these populations and control of their productive performances. They highlighted the defects of these populations, namely their too weak prolificacy and their low adult weight, but also their qualities, namely a good adaptation to the local climatic conditions, without any loss of productivity in summer (Lakabi *et al.* 2004; Zerrouki *et al.* 2005a and 2005b). To provide to the farmers more productive animals, the ITELV, in collaboration with the INRA, chose to create a synthetic line obtained by a crossing between a local population and the INRA 2666 strain (Gacem and Bolet 2005). After 4 generations of homogenization, this synthetic line was compared during 18 months to two local populations in the same conditions. The synthetic line's does were heavier (+200 to 420 g) and the observed litter size showed its superiority (+1.9 to 2.5 born alive) There was no genotype x season interactions which changed the genotypes ranking. It means that the synthetic line is as well adapted as local populations to local climatic conditions and much more productive. So, this comparison confirms the interest of this synthetic line to develop rabbit production in Algeria. It is now selected for litter size and weight at slaughter age with a BLUP index including direct and maternal effects and disseminated by ITELV to cooperatives and multiplication farms (Gacem *et al.* 2008, 2009; Lebas *et al.* 2010).

Table 1: Programs **used for developing synthetic lines in developing countries**

Synthetic line and origin	Founder breeds	Selection criteria	Selection methodology	Number of generations	Selection response per generation
Maternal lines:					
Saudi-2, Saudi Arabia, Khalil *et al.* (2005)	V line and Saudi Gabali	LWW + W12	BLUP animal-repeatability model	10	LSB= 0.18 kit/litter LSW= 0.16 kit/litter LWW= 62g/litter; WW= 8.6g/kit
APRI, Egypt, Youssef *et a.l* (2008)	V line, Baladi Red	LWW	BLUP animal-repeatability model	5	
Paternal lines:					
Alexandria, Egypt, El-Raffa, (2007)	Line V, Baladi Black	ADG (28-63d)	Individual selection using BLUP	5	
Saudi-3, Saudi Arabia, Khalil *et al.* (2002, 2005)	Line V and Saudi Gabali	LWW + W12	Individual selection using BLUP	8	W12= 38g; ADG= 0.6g; LSB= 0.14 kit/litter; LSW= 0.12 kit/litter; LWW= 35g/litter
Multi-purpose lines:					
ITELV, Algeria Gacem *et al.* (2008)	INRA2666 and local populations	LSB and 63 days weight (direct and maternal effects)	BLUP selection	4 (homogenization) +2(selection)	
Botucatu, Brazil, Moura *et al* (2001)	Norfolk English line	Weaning litter + ADG (28-70 d)	Selection index		
Moshtohor, Egypt, Iraqi *et al.*(2008)	Sinai Gabali, line V	LWW+ 56-d weight	Two-stage selection using BLUP		

LSB = litter size at birth; NBA= Number born alive; LSW = litter size at weaning; LWW= litter weight at weaning; WW = weaning weight; ADG: average daily gain; W12: weight at 12 weeks.

In Egypt, great efforts have been made since 1998 to select for one exotic maternal line under local conditions and to develop and select lines based partially on local breeds. An Egyptian-Spanish program was established involving Alexandria University, Animal Production Research Institute (APRI, Cairo) and Benha University. V-line rabbits were imported in 1998 from Spain and various selection experiments were practiced. The first line was developed from crossing Baladi Red with V-line and this maternal line named APRI was selected for litter weight at weaning (Youssef *et al.* 2008). A synthetic paternal line named Alexandria was originated in Alexandria University from crossing V line with Baladi Black and selection was practiced for daily weight gain during 28-63 days of age (El-Raffa 2007). In 2003, a selection program was started to produce a synthetic multi-purpose line named Moshtohor resulting from crossing Sinai Gabali with V-line and selection was practiced for litter weight at weaning and live weight at 56 days (Iraqi *et al.* 2007, 2008).

In Tunisia, local populations of the South West (Tozeur and Gafsa oases) have been characterized (Ben Larbi *et al.* 2008) and very poor performances have been evidenced. On another hand, European strains have been imported about 20 years ago and are maintained in some farms with a limited selection (Lebas and Bolet 2008). There is a strong political will to develop rabbit meat production in medium-size units. The ministry of agriculture and an interprofessional structure, the GIPAC, in collaboration with INRA, will develop in these farms a program of data recording to characterize these strains; afterwards, according to the results, a program of selection and diffusion will be implemented (Bouslama *et al.* unpublished data).

Sub-Saharan Africa.

In Benin, a nucleus of rabbits from local populations of the South Benin has been implemented in the CECURI (University of Abomey-Calavi) (Kpodekon and Coudert 1993) and, after many years of efforts focusing on sanitary aspects, a selection program has been recently initiated (Akpo *et al.* 2008) with the help of INRA. However, the project of crossing this local population with an INRA strain to create a synthetic line is in progress.

In Nigeria, Oseni (2008b) emphasized the lack of applied research for rabbit production; Abu et al (2008) and Oseni *et al.* (2008) characterized the weakness of traditional systems. Oseni (2008a) recently proposed a genetic improvement program; its strategy is to exploit locally available heterogeneous populations to create a closed nucleus, define breeding goals and selection criteria and provide backyard small units with improved animals.

Latin America.

In Brazil, a multi-purpose selection program was initiated in 1992 to develop a multipurpose line named Botucatu, using a selection index including litter size and weight at weaning and post-weaning growth traits (Moura *et al.* 2001).

In Mexico, a strategy of providing "Family packages" to promote the production and consumption of rabbit meat began many years ago and seems to continue (Mendoza *et al.* 2008), but no information is available about the origin and selection of bucks and does.

Selection responses:

In selection experiments carried out in developing countries, definite methodologies have been proposed to estimate selection responses. One of them is based on regressing the estimates of the breeding values on generations and this approach depends on the genetic parameters and the model used (Moura *et al.* 2001). The other methodologies use the control population which could be an unselected population (Khalil *et al.* 2002, 2005), or a divergently selected population (Moura *et al.* 1997).

As presented in Table 1, genetic responses obtained from long-term selection experiments for litter size and other litter traits were found to be moderate. Selection experiments for growth rate show successful responses in most experiments carried out in Brazil (Moura *et al.* 1997). Khalil and Al-Saef (2008) stated that does selected for litter size at weaning presented significant responses in feed intake (3%) and milk yield (6%). A response of 62 g per litter was recorded when selecting for litter weight at weaning. Estimates of direct selection responses per generation were moderate and ranged from 8.7 to 12.6 g for weaning weight, 18 to 68 g for marketing weight, 0.45 to 1.73 g/day for weight gain from weaning to marketing. Selection for growth rate had little or rather moderate effects on carcass characteristics and meat quality when the rabbits were selected at the same stage of maturity. Selection for litter weight at weaning achieved considerable responses in growth rate while maintaining high litter components and feed conversion.

Direct and maternal heterotic effects

For litter and lactation traits, different crossbreeding experiments carried out in Egypt (e.g. Khalil *et al.* 1995; Khalil and Afifi 2000; Abd El-Aziz *et al.* 2002; Iraqi *et al.* 2007; Youssef *et al.* 2009) indicated that direct heterotic effects were evidenced for litter size, litter weight, and milk yield in most of the possible crossbred does obtained. Consequently, both producers and processors in this area could potentially benefit economically through using crossbred does. Also, estimated maternal heterosis were favorable and indicate that crossbred dams had considerable maternal heterotic effects in terms of larger litter size, heavier litter weight at birth and weaning, favorable feed conversion ratio, and efficient milk to litter gain conversion ratio than their crossbred daughters (Khalil *et al.* 2005). Khalil and Afifi (2000) and Abd El-Aziz *et al.* (2002) reported that crossing Gabali rabbits with New Zealand White in Egypt was associated with negative low non-significant heterotic effects on milk yields during the first 21 days of suckling and the whole period of lactation (0.12 to 2.4 %).

For postweaning growth, estimates of direct heterosis for body weights raised in hot countries were mainly positive and ranging from 1.3 to 14.5 %, but the estimates for maternal heterosis were mainly negative and ranging from 0.2 to 5.3 %. Abdel-Ghany et al (2000) and Afifi *et al.* (1994) found that heterosis percentages ranged from 2.7 to 9.5% for post-weaning body weights and gains by crossing New Zealand White with Baladi Black or Baladi Red in Egypt.

For carcass traits, Afifi *et al.* (1994) found that direct heterosis percentages from crossing New Zealand White X Baladi Red in Egypt ranged from 1.0 to 4.7. In Saudi Arabia, Al-Saef *et al.* (2010) showed non-favorable negative estimates of maternal heterosis of -65.5 g, -6.7 g, -5.3 g and –12.2 g for hot carcass, offal, fat and bone weights, respectively. For meat quality traits, neither individual heterosis, nor maternal heterosis were significant.

For semen parameters, direct heterosis given by Khalil *et al.* (2007) indicated that crossbred bucks were associated with heterotic effects in some semen parameters. Such crossing was associated with an increase in ejaculate volume (11.6%; $P<0.05$), sperm concentration (10.5 %; $P<0.05$), percentages of motile (9.8%) and living sperms, and libido of bucks ($P<0.05$)

along with a reduction in percentages of abnormal (-10.8%) and dead sperms (-23.5%; P<0.05). Reviewed estimates of maternal heterosis for semen characteristics were favorable and moderate (Khalil *et al.* 2007). Consequently, crossbred dams could produce crossbred bucks characterized by higher volume of ejaculate, higher semen quality with more concentration and motile sperms, along with lesser percentages of abnormal sperms and dead sperms than their crossbred daughters.

QTL analyses in developing countries

Till now, marker-assisted selection (MAS) is not used in current rabbits' selection programs in developing countries and the recent molecular technologies were used only in these countries to detect the associations between phenotypic traits and genetic markers. Khalil *et al.* (2008) used RAPD markers to search for the linkage between markers and quantitative traits. From a total of 40 primers used in their study, five were polymorphic, and only three of them showed significant associations with phenotypic traits. El-Zarei (2010) detected five markers to differentiate between individuals and to study the association between these markers and some carcass, tissues composition traits and meat quality traits.

Conclusion

In developing countries, the most efficient strategy used is the development of synthetic lines, resulting from the crossing between local populations or breeds and selected European strains. These strains were provided essentially by the University of Valencia (Spain) and the INRA (France). They can be specialized maternal or paternal lines, or multi-purpose lines.

This solution allows to profit from the complementarity between local populations, well adapted to the environment and selected strains. It allows also to benefit from half of the heterosis. The favorable estimates of direct and maternal heterosis reviewed for reproduction, lactation, growth and carcass traits and heat-stress physiological parameters would be an encouraging factor for the rabbit producers in hot climate countries to use such lines.

Till now, marker-assisted selection (MAS) is not generally used in current rabbits' selection programs in developing countries and the recent molecular technologies were used only in these countries to look for associations between phenotypic traits and genetic markers.

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