TRANSFORMING SWAMP BUFFALOES TO PRODUCERS OF MILK AND MEAT THROUGH CROSSBREEDING AND BACKCROSSING

L.C. CRUZ

Philippine Carabao Center, Munoz, Nueva Ecija, Philippines

(Makalah diterima 24 Juli 2009 – Revisi 18 September 2009)

ABSTRACT

There are two major types of water buffaloes in the world, the riverine type and the swamp type. The total number of Swamp buffalo is 37.6 M and represents 21.8% of the world's buffalo population. The swamp buffaloes have played a major role in draft animal-dependent farming system. But intensified rice production became more pronounced in irrigated areas and this has led to increased utilization of small farm machineries, displacing significantly the draft buffaloes for land tillage. To some extent, the introduction of tractors for land preparation and transport for corn, sugarcane and other crops in production areas has similar effect. Utilization of the existing population of swamp buffaloes to meet the growing domestic demand for milk and meat, against the background of increasing farm mechanization, is a good reason to transform the huge number of draft animals into producers of milk and meat. According to the UNDP/FAO-assisted project in the Philippines carried from 1982 to 1998, that crossing swamp buffalo and riverine buffaloes, despite the differences in chromosome numbers, is producing crossbreds with high growth rate potentials and milk production abilities several folds over the swamp buffalo parents. The known fact that swamp and riverine buffaloes have different chromosome number, the diploid chromosome number of the swamp buffalo is 48 and that of the river buffalo is 50. When crossbreeding between the 2 buffalo types occur, males and females of the F_1 generation are heterozygous for the fusion and are apparently fertile with chromosome 2n = 49. Three-way crossbred hybrids were obtained by (native buffalo x Murrah x Nili Ravi) or (native buffalo x Nili Ravi x Murrah). They had two chromosome categories viz. 2n=49 and 2n=50, respectively. Crossbreeding Swamp with Riverine Breed is done for quality beef**.** Most of the NT produced TenderBuff is farm-bred or purchased from other suppliers as swamp buffalo yearlings and growth out for a further 8 – 16 months to achieve target weights on the pastures. The reproductive performance of F_1 females produced out of crossing Murrah buffalo and Philippine carabao are not different. Assessment of the fertility of F_1 bulls was made on the basis of the pregnancy rate obtained from AI on Philippine carabaos using frozen semen. The data indicated that there was no significant difference between the pregnancy rate of the Philippine carabaos inseminated with either Murrah buffaloes or F_1 frozen semen. However, a signigicant difference on conception rate was observed ($P < 0.05$) compared to hybrid with 2n = 50 chromosomes. The calving rate of hybrids with 2n = 49 chromosomes decreased by 17.77 – 17.89% and the total calves reduced by 1.33 – 1.54 heads from the first calving to age of 11 years. The fundamental initiative that is most consistent with the envisaged improvement in the productivity of the carabao is the establishment of germplasm pools from where superior materials can be obtained on a sustainable basis such as Gene Pools for Selected Native Philippine Carabao (PC), Gene Pool for Riverine Buffalo for Meat Improvement, Gene Pool for Improvement for Milk Production. From the above point of view, the future will see sustained and more intensive efforts to pursue the goal of transforming genetically the traditionally draft animal to producer of milk and meat and eventually establishment of viable and progressive buffalo-based enterprises.

Key words: Swamp buffalo, crossbreeding, backcrossing

ABSTRAK

PEMBENTUKAN KERBAU LUMPUR MENJADI PRODUSEN SUSU DAN DAGING MELALUI PERSILANGAN (*CROSSBREEDING*) DAN PERSILANGAN BALIK (*BACKCROSSING*)

Di dunia terdapat dua golongan kerbau air yaitu kerbau lumpur dan kerbau sungai. Jumlah kerbau lumpur sekitar 37,6 milyar ekor atau 21,3% dari total populasi kerbau dunia. Kerbau lumpur mempunyai peran penting dalam dunia pertanian yang masih menggunakan bajak untuk mengolah tanah. Akan tetapi intensifikasi produksi beras telah banyak menggunakan mesin pembajak, sehingga peran kerbau sebagai pembantu petani tersisihkan. Pemanfaatan daging kerbau untuk memenuhi peningkatan permintaan daging dan susu menjadi sangat mungkin dilakukan. Kerjasama FAO/UNDP dengan Filipina selama 1982 – 1998 memperlihatkan bahwa persilangan antara kerbau lumpur dengan kerbau sungai menghasilkan tingkat pertumbuhan dan kemampuan produksi susu yang meningkat dibandingkan dengan tetuanya. Walaupun kedua jenis kerbau tersebut memiliki jumlah kromosom yang berbeda, yaitu 50 untuk kerbau sungai dan 48 untuk kerbau lumpur, hasil persilangan antara kedua kerbau tersebut menghasilkan keturunan (F1) yang heterozigos dan fertil dengan jumlah kromosom 2n = 49. Persilangan tiga bangsa kerbau (kerbau lokal x Murrah x Nili Ravi) atau (kerbau lokal x Nili Ravi x Murrah) menghasilkan ternak dengan jumlah kromosom yang berbeda: 2n = 49 dan 2n = 50. Persilangan antara kerbau lumpur dan kerbau sungai dilakukan untuk menghasilkan daging berkualitas tinggi dengan digembalakan di padang penggembalaan yang sangat baik. Sedangkan uji kemampuan reproduksi pada F1 jantan dari persilangan tersebut dilakukan berdasarkan tingkat kebuntingan yang diperoleh dengan menggunakan inseminasi buatan. Data menunjukkan tidak terdapat perbedaan yang nyata antara tingkat kebuntingan kerbau Filipina yang diinseminasi dengan semen kerbau Murrah atau semen kerbau F1. Akan tetapi terdapat perbedaan yang nyata pada *conception rate*. Untuk tingkat beranak (*calving rate*) pada sapi dengan kromosom 2n = 49 menurun 17,77 – 17,89% dibandingkan sapi dengan kromosom 2n = 50, dan jumlah anak menurun l,33 – 1,54 ekor sejak beranak sampai umur 11 tahun. Untuk keperluan persilangan ini telah dibentuk *Gene Pool* untuk mendapatkan kerbau-kerbau berkualitas seperti kerbau Filipina, kerbau sungai untuk perbaikan kualitas daging, dan kerbau berkualitas untuk keperluan meningkatkan produksi susu. Dari uraian tersebut di atas, di masa mendatang diharapkan akan terwujud perubahan kerbau sebagai penarik bajak menjadi kerbau penghasil daging dan susu.

Kata kunci: Kerbau lumpur, *crossbreeding*, *backcrossing*

INTRODUCTION

There are two major types of water buffaloes in the world, the **riverine type**, generally are dairy breed and are found in Indian continent covering India, Pakistan, Bangladesh, Nepal, Sri Lanka, and in European countries, and the **swamp type**, found in China and Southeast Asia.

The total number of swamp buffalo is 37.6 M and represents 21.8% of the world's buffalo population. The history of swamp buffalo is basically a history of small-hold land-based agriculture, since for centuries, the swamp buffaloes have played a major role in draft animal-dependent farming system, mainly in the production of major agricultural crops, such as rice, corn, sugarcane and coconut. In recent years, however, developments in land-based agriculture such as the expansion of irrigation facilities have had significant impact on the use of draft buffaloes. Intensified rice production became more pronounced in irrigated areas and this has led to increased utilization of small farm machineries, displacing significantly the draft buffaloes for land tillage. To some extent, the introduction of tractors for land preparation and transport for corn, sugarcane and other crops in production areas has similar effect.

In view of the intensification in land use and increasing farm mechanization, the interest in developing swamp buffaloes beyond being a draft animal, to improving the genetic potentials for meat and milk, through crossing with riverine type buffaloes becomes profound. This lends more meaning in the light of the need to address the growing issue of low income among smallholder farming families amidst the rising cost of farm inputs, creating significant impact on the net income derived from the traditional crop-dominant farming system. The technical aspect of such crossbreeding has been a subject of research interest for several years in view of the known differences in their chromosome numbers, swamp buffalo has 2n=48 while the riverine type has 2n = 50.

SOCIAL AND ECONOMIC CONSIDERATIONS IN SWAMP BUFFALO CROSSBREEDING

Human population and swamp buffaloes. Human population in China and SEA countries with substantial swamp buffalo population is about 1.92 billion, representing 28.33% of the world's population. What is of interest is the fact that about 1.1 billion of these people depend on agriculture (Table 1), and that among those people in land-based agriculture, the size of land holdings becomes smaller over the years. Additionally, the rise in oil price in recent years has significant impact on cost of farm inputs, essentially the oil-based products such as fuel and fertilizer rendering the cost of production to increase considerably. In grain producing countries, this has created a shift in the use of grains for the production of biofuel.

Collectively, these array developments have resulted in upward movement of food prices, with the rural farming families tightly caught in a situation of declining net income and reduced purchasing power. Undeniably, measures to generate sources of additional income for the millions of farming families is a priority consideration.

One prominent resource common among the smallholder farming families is their swamp buffaloes. In China and Southeast Asian countries, there are about 37.9 M of these animals (Table 1), each family would have 1 – 3 heads, on the average. For hundreds of years, these swamp buffaloes are used mainly for draft, and perhaps still a good percentage of the farming families shall depend on this animal resource for the same purpose in the many years to come.

It is also true that there are substantial land areas that are now under intensive use owing largely to the development of major irrigation systems, coupled with the advent of small-sized farm machineries. In these areas, significant substitution has been taken place, with increasing number of farm tractors and declining usage of draft buffaloes. In fact, the intensive farm

Table1. Human and swamp buffalo population in China and Southeast Asia

Country	Human population in 2009 (million)	Human Population in agriculture (%)	No. of human population in agriculture (million)	Buffalo/ human	Buffalo population in 2007
China	1,331.4	63.15	840.1	0.017	22,722,010
Cambodia	14.8	67.72	10.0	0.052	774,000
Indonesia	243.3	40.15	97.5	0.009	2,085,780
Lao People's Democratic Republic	6.3	75.45	5.2	0.178	1,120,000
Malaysia	28.3	13.84	3.9	0.005	130,000
Myanmar	50.0	68.29	34.1	0.057	2,841,733
Philippines	92.2	35.76	33.0	0.037	3,383,620
Thailand	67.8	44.21	29.9	0.026	1,743,546
Timor-Leste	1.1	81.06	0.8	0.100	110,000
Vietnam	87.3	64.86	57.8	0.034	2,996,400
Total	1,922.5		1,112.3		37,904,000

Source: FAO (2007)

mechanization in Taiwan, Malaysia, and Thailand is the single major reason for the decline in swamp buffalo population in those countries in the early 1970s and 80s. Water buffalo in Taiwan is now considered endangered species. In Malaysia, the role of buffaloes in the over all livestock sector is less than 4.0% (ABAS, 2006).

Increase demand for milk and meat. Many Asian countries have registered sustained economic growth in the recent years and this has also resulted in increase establishment of urbanized areas. The rise in income among urban population has also brought about a corresponding shift in food preference as demonstrated in the rise in demand for beef and milk. With the reduced land area for grazing and forage production, the only immediate option to meet the growing requirements is increase in imports of milk and beef in recent years.

Southeast Asia (SEA) is net importer of milk and dairy products with Philippines and Malaysia importing almost 99% of their requirements while Indonesia and Thailand import 61.5% and 50.0%, of milk and dairy requirements, respectively. On the other hand, China's dairy industry is growing in concert with its extremely fast economic growth, thus with barely 3.2% imports only (Table 2).

It is easy to understand that sudden rise in meat demand in fast growing population of Asia can be met by intensive production of chicken and pork. This has taken place in China and Southeast Asian countries in significant magnitude, of course with corresponding increases in imports of feed-grains. Requirements for beef in these countries are met by massive imports of buffalo meat from India, with Malaysia and the Philippines leading with 75.2% and 35.8% of domestic requirements, respectively, coming from importation. Indonesia imports about 15.7% of its beef requirements whereas China is nearly self-sufficient with only 2.6% of its requirements coming from imports (Table 2).

Table 2. Milk and beef sufficiency level of China and selected SEA countries

Country	Milk (million tons)			Beef (thousand tons)		
	Production	Import/export	% Sufficiency	Production	Import/export	% Sufficiency
China	41.9	1.4	96.8	6510	170	97.4
Indonesia	1.0	1.6	38.5	480	90	84.3
Malaysia	-	1.0	0.01	27	82	24.8
Philippines	-	1.1	0.01	250	140	64.2
Thailand	0.7	.07	50.0	-	-	-

Source: FAO (2009)

As a long-term development strategy, however, efforts in fast-growing economies in Asia have also included programs to enhance growth in their respective local dairy industry with massive infusion of stocks of "tropicalized" dairy cattle from Australia and New Zealand. This development approach is becoming more meaningful in most of the Asian countries that remain net importers of milk and dairy products as prices of milk in the international market have surged in view of the policy and regulatory measures in some exporting countries and also due to unfavorable climatic factors that resulted in reduced production and thus in traded milk in the international market. But with the rising demand for same dairy animals for restocking farms in post-BSE Europe and Latin America, prices of dairy breeder stocks have also significantly increased lately. This is further compounded by depreciation of local currencies against the US dollar reducing importation of dairy cattlestocks for commercial production less economically viable.

Transforming swamp buffaloes to producers of milk and meat. Utilization of the existing population of swamp buffaloes in hot and humid tropics and harnessing the age-tested abilities of the smallholds farmers to rear these animals to provide opportunities for millions of smallholder farming families to earn additional income, and also to meet the growing domestic demand for milk and meat, against the background of increasing farm mechanization, are good reasons to transform the huge number of draft animals into producers of milk and meat. The UNDP/FAO-assisted project in the Philippines carried from 1982 to 1998, and the subsequent expansion of upgrading program have clearly proven that crossing swamp buffalo and riverine buffaloes, despite the differences in chromosome numbers, are producing crossbreds with high growth rate potentials and with milk production abilities several folds over the swamp buffalo parents.

In view of the fact that low cost labor for rearing these animals are abundant among farming families, the cost of production for milk and meat from crossbred buffaloes becomes competitive. Given the net income derived from crop-dominant farming system as reference, it has been demonstrated that net income from milk of one to two crossbreds is sufficient to double the income of smallholder family having a hectare of rice. The added advantage in dairying is the derivation of cash income on a daily basis from the sales of milk while on the long wait for harvests from crops.

TECHNICAL CONSIDERATIONS IN THE SWAMP BUFFALO TRANSFORMATION

Chromosomal analysis of water buffaloes and their crosses. The interest among scientists in the past has been anchored on the known fact that swamp and riverine buffaloes have different chromosome number, the diploid chromosome number of the swamp buffalo is 48 and that of the river buffalo is 50. The reduction in chromosome number in swamp buffalo is seen as the tandem fusion (telomere - centromere) of chromosome pair 4 and 9 of riverine karyotype. When crossbreeding between the 2 buffalo types occur, males and females of the F_1 generation are heterozygous for the fusion and are apparently fertile with chromosome 2n = 49. It had been reported that the F1 river x swamp crosses had chromosomes numbers 2n = 49. Of the chromosomes, 3 chromosomes included one metacentric; one submetacentric and one telocentric chromosome were not in pair. Through the G-band analysis, it was demonstrated that the metacentric chromosome in the three unpaired chromosomes belonged to the chromosome 1 swamp buffalo, and the others two chromosomes were response to chromosome 1 and 9, respectively, from river buffaloes, which may be homologous as they had type of G-band (HUANG, 2006).

Inter-se mating of F_1 produce the F_2 hybrid of three different karyotype categories (*2n* = 48, *2n* = 49 and *2n* = 50). Backcrosses (75:25) produced out of mating F_1 (50 : 50) with swamp buffalo karyotype categories are *2n* = 48 and *2n* = 49. On the other hand, if F_1 (50 : 50) is backcrossed with riverine buffalo the resulting F_2 (75 : 25) has karyotypes of *2n* = 49 and *2n* = 50.

Three-way crossbred hybrids were obtained by (native buffalo x Murrah x Nili Ravi) or (native buffalo x Nili Ravi x Murrah). They had two chromosome categories viz. 2n = 49 and 2n = 50, respectively. The two types of karotype were not only existed in the progeny of three-way crosses, but also on the F_2 hybrids and F_3 hybrids of grading crosses. It could be observed that during the meiotic division, the F_1 hybrid with 2n = 49 chromosomes produced 24 synaptonemal complexes (SC) which consisted of 22 divalents, an autosomes trivalent and a XX divalents. During the synapsis, the meme 1 from swamp buffalo undergoes partial alignment with submetacentric chromosome 1 and telecentric chromosome 9 from river buffaloes. The synapsis was kept up until metaphase 1. The disjunction occurred during anaphase 1 when it was observed that the metacentric chromosome 1 from swamp buffalo was pulled one pole to another pole, which resulted in production of two types of sperms viz. n = 24 and n = 25, respectively. The male river buffalo (2n = 50 + produced only one type of sperm (n = 25). Therefore, the hybrids of three-way crossbred and F_1 and F_2 grading crossbred hybrids had two types of karotypes viz. 2n = 49 and 2n = 50. The ratio of the types of karotypes was near 1:1 in the hybrids of three-way crossbred and the F_1 grading crossbred hybrids.

Chi-square tests on pooled data indicated that the distribution 1 : 2 : 1 ratio expected if only balanced gametes with 24 and 25 chromosomes are produced by the F_1 hybrids. In the three quarters swamp and three quarters river types, the respective karyotypic categories are in ratios approximating 1 : 1. The distribution of chromosome categories among the F_2 hybrids and backcrosses suggests that only genetically balanced gametes of the F_1 hybrids are capable of producing viable F_2 and backcross generations (BONGSO *et al.*, 1983).

DAI *et al.* (1994), described the Snynaptonemal Complexes (SC) karyotypes of swamp, river and hybrid water buffaloes as follows:

2n = 50 group (river and ¾ river). – Among the autosomal bivalents, there were five submetacentric and nineteen acrocentric SCs. There were six NOR-bearing bivalents: two submetacentrics, one large and three small acrocentrics. The nucleoli were located at telomeres of these SCs. The mean absolute length of SC karyotype was 214.4µm (n = 27, SD = 32.4) for the river buffalo and 195.9 µm (n = 333, SD = 31.4) for the ¾ hybrids.

2n = 48 groups (swamp, F_2, and ¾ swamp). – The autosomal bivalents included a metacentric (the longest SC), four submetacentric, and eighteen acrocentric SCs. Five nucleoli were terminally located on one submetacentric, one large and three small acrocentrics. The mean absolute lengths of SC karyotype were 171.8 µm (n = 20, SD = 27.1) for the swamp buffalo and 186.9 µm (n = 48, SD = 30.1) for the hybrids.

2n = 49 groups (F_1, F_2, and ¾ swamp). – There were four submetacentric and eighteen acrocentric autosome bivalents, and a trivalent. The trivalent was composed of a metacentric, one NOR-bearing submetacentric, and one acrocentric. Six nucleoli were located on a submetacentric and four acrocentric bivalents, and the trivalent. The mean absolute length of the SC karyotype for all $2n$ = 49 hybrids was 194.9 µm (n = 65, SD + 25.3).

Among the F_2 and ¾ swamp bulls, those with a karyotype of $2n$ = 49 has a higher abnormality frequency (63 – 68%) than those with $2n$ = 48, not significantly different from the F_1 (73%). The frequency of abnormal configurations caused by interactions among nontrivalent SCs was lower in the $2n$ = 49 group than in the $2n$ = 48 and $2n$ = 50 hybrids, confirming that when a trivalent is present in the karyotype the asynaptic regions on the autosomes or the X and Y tended to interact with the trivalent (DAI *et al.*, 1994).

The data from SC analysis are consistent with those from semen investigations which have shown that spermatozoa abnormality is lower in the swamp bulls (8.95 – 10.3%) than in the river bulls (12.28 – 20.8%; BARKER *et al.*, 1991). The abnomal sperm percentage was 52.4% in the F_1 (SITUMORANG and SITEPU 1991), 30.7% in the $2n$ = 49 ¾ swamp bull, and 53.4% in the $2n$ = 49 ¾ river bulls (BARKER *et al.*, 1991), while it was 9.78% in the $2n$ = 48 ¾ swamp bulls and 19.8% in the $2n$ = 50 ¾ river bulls (BARKER *et al.*, 1991) Histological observations showed spermatogenic arrest in half of the testis tubules from F_1 and $2n$ = 50 backcross bull, but in less than one sixth of tubules from a purebred swamp bull. Reduced quantity and quality of sperm can be expected to follow high abnormality frequency in SC preparations.

Histological examination of the hybrid testis revealed a large proportion of degenerating spermatocytes and abnormal spermatids in the process of spermiogenesis suggesting that the various synaptic associations leading to unbalanced gametes may be responsible for the degenerating germ cells in the hybrids. The unbalanced meiotic products will probably lead to selection against such spermatozoa or early embryos after fertilization. Due to a large percentage of germinal epithelial cells in F_1 hybrids being wasted, the fertility of backcross and F_2 generations will be subnormal (HARISAH *et al.*, 1989).

Implementation of crossbreeding and backcrossing. There are only two countries in Asia that are pursuing large scale crossbreeding and backcrossing of swamp buffaloes with the intent to produce critical population of animals with higher genetic potentials for milk and meat production, namely, China and the Philippines.

Crossbreeding and backcrossing in the Philippines were limited before 1974, few years after creation of Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD). Serious consideration on crossing swamp buffalo with the riverine type was initiated after 10-year United Nations Development Programme-Food and Agriculture Organization (UNDP-FAO) assistance on buffalo R&D was approved and implemented in 1982 to 1992. This 10-year research initiatives clearly defined the benefits of crossing the riverine buffaloes (Murrah) (2N = 50) with the Philippine swamp (2N = 48). The resulting F1 crossbreeds were found to grow significantly faster than the swamp buffalo and to produce milk three to four times more than the native parents. It was also demonstrated males and females that the F1 crossbreds (2N = 49) are fertile. Moreover, backcrosses with increasing blood composition of the riverine breed registered linear increment in milk yield without detrimental to the reproductive and adoptive performances. With these production potentials, the social and economic benefits accruing to rural farmers from raising crossbred carabaos instead of the local breed became pronounced.

On the basis of these encouraging results, the government implemented a national artificial program on swamp buffaloes utilizing frozen semen of selected Murrah sires. And thus, in view of the growing need for frozen buffalo semen for AI, the establishment of the first frozen buffalo semen laboratory in the country was initiated in 1984. Estrous synchronization procedure was also developed to permit synchronized breeding and allowed the coverage of many breedable females, which are scattered so thinly in the villages all over the country, utilizing the relatively few available AI technicians.

The breeding scheme followed in the Philippines is described below:

Swamp (S) x Murrah (M)
F_1 SM (50 : 50)

↓

SM x M (75 : 25)

↓

SMM x M (87.5 : 12.5)

↓

SMMM x M (93.75 : 6.25)

The backcrossing is aimed at producing backcrosses at least at 3rd and 4th generations. The introduction of the dairy breed of buffalo in the Philippines first occurred with the importation of 67 head of Murrah buffaloes from India in 1918. A few batches of dairy buffaloes were also imported in subsequent years. Due to the absence of an organized breeding program, however, the introduction of riverine bloodlines in the earlier years resulted in crossbreds of varying blood composition in the surrounding areas of the breeding stations and eventual loss of a large percentage of the purebred animals.

Fresh genetics were infused into the country in the early 80s with the importation of frozen semen of the Murrah breed from India through the UNDP-FAO funded project. This was followed by importation of live riverine buffalo stocks between 1994 and 1998 (Table 3). In 1994, "American Murrah" buffaloes (150 females and 70 males) were bought from the USA to improve the meat production potentials of the local carabaos. The American breeder combined the growth potentials of the Jafarrabadi breed with that of the Indian Murrah and the swamp buffalo from Guam in developing the line. On the other hand, 3,183 heads of "Bulgarian Murrah" stocks were imported in 1995 – 1999 for use in improving milk production potentials. The animals from Bulgaria have the advantage of having been selected for milk production for at least three generations. These importations were further augmented with the infusion into the country of about 13,000 doses of frozen semen from the top three progeny-tested bulls of Bulgaria.

Table 3. Recent importations of Riverine buffalo breeder stocks, Philippines

Year	Number	Source	Important traits/usage
1994	237	USA	Meat
1995	459	Bulgaria	Milk
1996	403	Bulgaria	Milk
1998	1656	Bulgaria	Milk
1999	605	Bulgaria	Milk

Very recently, the government approved the infusion of 2000 heads of dairy type buffaloes from Brazil and the animals are due to arrive by the end of 2009. These germplasm infusions are designed to hasten the envisaged wide scale transformation of swamp buffaloes as producers of milk and meat in the immediate future.

Aggressive crossbreeding and backcrossing have been pursued in China, the country that has the largest population of swamp buffalo in the world (FAO, 2007) numbering to about 22.7 Million. Organized crossbreeding of swamp and riverine buffaloes were initiated as early as 1957 with the importation of Murrah breed from India and followed by infusion of another riverine buffalo breed, Nili Ravi in 1974 through donation from Pakistan government. The national buffalo improvement program was initiated in 1974 although as early as 1973, there was a massive AI program, establishing semen processing laboratories in 5 of 15 provinces (Guangxi, Shanxi, Guangzhou, Hubei and Guangdong) representing areas where there is high density of swamp buffaloes. By 1975, the program reported to have produced 16,930 heads of F_1 crossbreds and by 1985, the crossbred population increased by about 8 folds (150,000 heads). The Chinese government saw it fit to create a National Buffalo Development Program Team in 1989 and which grew into the development of Dairy Buffalo Industry in Southern China in 1991. Under this program, Guangxi Province became the national pilot area for Buffalo Dairying in 1994 and the host of the Buffalo Research Institute, in cooperation with Chinese Academy of Agricultural Sciences in 1995. The institute was strengthened with the EU-China Buffalo Program in 1996. Chinese crossbreeding and backcrossing involves three breeds, the Chinese native swamp buffalo, the Indian Murrah and the Nili-Ravi from Pakistan. The schemes are shown below:

a) Swamp (S) x Murrah (M)
F_1 SM (50 : 50)
↓
SM x M (75 : 25)
↓
SMM x M (87.5 : 12.5)
↓
SMMM x M (93.75 : 6.25)

b) Swamp (S) x Nili-Ravi (N)
F_1 SN (50 : 50)
↓
SN x N (75 : 25)
↓
SNN x N (87.5 : 12.5)
↓
SNNN x N (93.75 : 6.25)

c) Swamp (S) x Murrah (M)
F_1 SM (50 : 50)
↓
SM x N (50 : 25 : 25)

Milk yield performance of crosses and backcrosses

Chinese swamp buffalo has generally low milk production between 500 – 800 kg/production (YANG *et al.*, 2007), however, selected Chinese swamp buffaloes have higher milk yield as in the case of animals at government institutions where recorded average milk production is 1,092.8 kg per lactation. Under similar conditions, purebred Murrah and Nili Ravi milk yield/lactation were reported to be 2,132.9 kg and 2,262.1 kg, respectively (YANG *et al.*, 2004).

The F_1 crosses of swamp buffalo with Murrah breed had average of 1,233.3 kg milk/lactation, equivalent to 12.3% increase in milk production. In the Philippines, the recorded yield of swamp buffalo x Murrah crosses is 4.14 kg/day and represents 176.0% increase, mainly because the milk yield of Philippine swamp buffalo is only 1.5 kg/day on the average.

Table 4. Milk production parameters of different buffalo pure breeds, crossbreds and backcrosses

Breed	Head	Lactation length (day) CV %	Milk yield (kg) CV%	Average milk yield per day (kg)	Corrected 305 – day milk yield (kg) CV%	Highest daily milk yield (kg)
L	70	280.4 ± 20.2 7.2	1092.8 ± 207.44 19.0	3.79		6.60
M	65	324.7 ± 73.6 22.7	2132.9 ± 578.3 27.1	6.57	2117.1 ± 430.0 20.3	17.40
N	58	316.8 ± 76.1 27.2	2262.1 ± 663.0 29.3	7.14	2366.4 ± 51.6 23.7	18.40
MLF_1	73	280.1 ± 76.1 27.2	1233.3 ± 529.7 42.9	4.40		16.50
MLF_2	16	303.2 ± 83.1 27.4	1585.5 ± 620.6 39.1	5.22		13.00
NLF_1	6	326.7 ± 96.4 29.5	2041.2 ± 540.9 32.4	6.25	2060.7 ± 386.2 18.7	16.65
NLF_2	9	325.8 ± 93.2 28.6	2267.6 ± 774.8 34.2	6.96	2298.4 ± 6044.4 26.4	18.37
$NMLF_2$	45	317.6 ± 78.4 24.7	2294.6 ± 772.1 33.7	7.22	2348.0 ± 533.2 22.7	18.80

L = Chinese Swamp buffalo (this represent selected animals); M = Murrah; N = Nili Ravi; MLF1 = F1 cross Murrah x Swamp; MLF2 = F1 Murrah (Backcross); NLF1 = cross Nili Ravi x Swamp; NLF2 = F1 x Nili Ravi (Backcross); NMLF2 = (M x L) crossbred x Nili (triplecross)

Source: YANG *et al.* (2004); ZHANG (2006)

On the other hand, Chinese swamp buffalo crossed with Nili Ravi registered milk yield of 2,041.2 kg/lactation, an increase of 86.9% over the swamp buffalo parents.

Backcrossing the (MxL) F_1 with Murrah or NL F_1 with Nili Ravi resulted in milk yield of 1,585.5kg and 2,267.6 kg/lactation, respectively. Clearly, the backcrosses with 75% riverine blood line have high milk yield than F_1 crosses. Among the Murrah backcrosses, the increase over the swamp parents is 45% and 28.5% over the F_1 cross. Similar trend is demonstrated among Nili Ravi backcrosses, with reported increases of 107.5% compared to swamp parents and 11.0% compared to NLF_1 crossbreds.

GROWTH AND MEAT PRODUCTION

Growth performance of swamp buffalo, and their crosses with Murrah breed are shown in Tables 5 and 6. There is no difference in birth weight between the two breeds groups, however, the growth rate of crossbreds started to move ahead than the swamp buffaloes starting at age of 6 months up until 36 months, with growth advantage that ranged from 10 – 31.1%. At four years of age, F_1 crossbred (50 : 50) and backcrosses with 75% Murrah blood have registered weight advantage of 9.8 and to 21.4% over the swamp parents.

Tender buff refers to buffalo meat with desired carcass quality specifications. Weight gains need to be around 200kgs of live weight gain on an annual basis. Rates of weight gain should be from 0.8 – 1.2 kg/head/day. Depending on starting weights, the required finish and temperament can be achieved over 60 – 120 day period of feeding depending on feed quality.

Table 5. Liveweight (kg) from birth to 36 months of age of swamp buffalo and F_1 (50 : 50) cross with riverine type

Age	Swamp Buffalo	F_1 Cross (50 : 50)	Difference (%)
Birth	31.4	31.1	1.0
6 mos	100.3	110.4	10.1
12 mos	132.5	170.9	29.0
18 mos	196.6	244.5	24.4
24 mos	213.9	255.9	19.6
30 mos	225.9	296.3	31.2
36 mos	260.9	333.6	27.9

In the “wet” season, growth rates of 1kg/head/day can be expected from the available pastures provided there is ample material available to buffalo (not overstocked) and a maintenance fertilizer program is adopted which supplies at least P and S and also K if needed.

Crossbreeding swamp with riverine breed for quality beef. Most of the NT produced TenderBuff is farm-bred or purchased from other suppliers as swamp buffalo yearlings and growth out for a further 8 – 16 months to achieve target weights on the above pastures. The stock are regularly weighted at 3 monthly intervals, then more often as target weights are approached. Batch groups are assembled when 380kg is achieved and then these groups are weighted virtually on a fortnightly basis until turned off. Ultrasounds P8 fat measurements are also taken to ensure fat specifications are met. By this stage, most buffalo are sufficiently yard trained to go through the QA system without any stress induced pH problems. The duration of the feeding period is a vital part of the

Table 6. Liveweight of Swamp buffalo and its crosses with Riverine breed, kg

Breed/type	N	Age, yearr	Liveweight, kg	Δ% [a]
Swamp				
Male	79	4 – 5	443	-
Female	92	4 – 5	398	-
SB x M (50 : 50)				
Male	11	4 – 5	531	19.8%
Female	19	4 – 5	476	14.5%
SB x M (25 : 75)				
Male	8	4 – 5	530	19.6%
Female	7	4 – 5	479	20.3%
SB x Nili (50 : 50)				
Male	15	4	538	21.4%
Female	18	4	482	21.1%

Source: FAYLON (1992); [a] Δ % increase over the swamp buffalo parents quartering process, to reduce the likelihood of stress at slaughter. Individuals that show no signs of settling down need to be segregated from the rest of the group as poor temperament in one animal can rapidly produce similar behavior in the rest of the mob.

In Australia, the introduction of Riverine blood from the USA during 1994 – 1997 has radically altered the productivity of TenderBuff. Growth rates in the crossbred from 3/8 and above are outstandingly greater than the purebred swamp available in the NT. 40% improvement in growth rates has been recorded in comparisons. Results from the NT Government Beatrice Hill Farm regularly confirm this trend. The more crossbred carcasses that are processed, the better the production data becomes. An example from 2003 – 2004 tenderBuff slaughtering is Table 7.

Table 7. An example tenderBuff slaughtering from 2003 – 2004

Parameter	Swamp	River crosses	(%)Difference over swamp
No of animals	52	24	
Mean HSCM (kg)	224.6	258.9	15.3%
Eye muscle area (cm^2)	57.1	70.0	22.6%
Mean pH	5.5	5.5	-1.5%
Mean carcass length (cm)	104.0	108.6	4.4%
Mean grid ($/kg)	3.05	2.96	-3.0%
Mean p8 fat (mm)	7.1	10.0	40.8%
Mean dressing (%)	51.2	51.7	1.0%
Mean price ($)	686.07	768.68	12.0%

Source: LEMCKE (2004)

Reproductive performance of F_1 crossbreds

Reproductive performance of females crossbreds. The reproductive performance of F_1 females produced out of crossing Murrah buffalo and Philippine carabao are not different (HUANG, 2006). It has been demonstrated that no difference was observed on the first calving age, gestation length and first estrus between the three-way crossbreed hybrids with 2n = 50 chromosomes and those with 2n = 49 chromosomes. However, significant difference on the calving interval was detected between these types of hybrids.

There was no significant difference on annual conception rate between the two types of hybrids ($P > 0.05$). However, a significant difference on conception rate was observed ($P < 0.05$). Compared to hybrids with 2n = 50 chromosomes, the calving rate of hybrids with 2n = 49 chromosomes decreased by 17.77 to 17.89% and the total calves reduced by 1.33 to 1.54 heads from the first calving to age of 11 years. The reduced reproductive performance in hybrid (2n = 49) may be resulted from the unbalanced gametes can not survive and produce conceptus.

Assessment of semen quality of Murrah buffaloes, crossbreds, and Philippine carabaos. Assessment of semen parameters obtained in one year from Murrah buffalo and crossbreds bulls indicated that the crossbreds would tend to have significantly lower initial sperm motility and semen volume than the Murrah.

Incidence of ejaculates with less than 50% initial motility was also significantly higher among crossbreds. These parameters indicated that in terms of total sperm output and total quality, Murrah bulls had advantage over the crossbred. However, in a separate study, the crossbreds appeared to be better than the Philippine carabaos in those parameters (NABHEERONG *et al.,* 1991).

A closer look on semen quality of Murrah buffalo and crossbred bulls of practically the same age (three to four years old), common nutrition and management, and with the same semen collection frequencies, confirmed that Murrah bulls were better than crossbreds in semen volume and initial motility, and sperm concentrations (Table 8 and 9).

The semen freezing process appeared to have inflicted less toll on the motility of the crossbreds than that of Murrah. The semen trend holds true on the percent change on the incidence of abnormal sperm associated with storage of frozen semen (Table 10).

Assessment of reproductive performance of hybrid bulls distributed for breeding. Assessment of the fertility of F_1 bulls was made on the basis of the pregnancy rate obtained from AI on Philippine carabaos using frozen semen. The data indicated that there was no significant differences between the pregnancy rate of the Philippine carabaos inseminated with either Murrah buffaloes or F_1 frozen semen. (Table 11).

INSTITUTIONALIZATION OF THE NATIONAL BUFFALO DEVELOPMENT PROGRAM

Establishing the ground for genetic improvement

The fundamental initiative that is most consistent with the envisaged improvement in the productivity of the carabao is the establishment of germplasm pools from where superior materials can be obtained on a sustainable basis. Efforts along this line have yielded concrete results, as follows:

Gene pools for selected native Philippine carabao (PC) – While exotic germplasm was introduced for the specific purpose of improving milk and meat, the government also ensured that the existing carabao

Table 8. Mean ± SE semen characteristics of Murrah buffalo (MB) and F_1 crosses (CB), PCRDC-CLSU, January – December 1990

Parameter	MB	CB
Volume, ml	2.8 ± 0.09[a] (735)	2.08 ± 0.2[b] (444)
Initial motility (%)	61.8 ± 4.60[a] (735)	45.5 ± 11.4[b] (444)
Sperm concentration (10^7/ml)	88.4 ± 8.60[a] (710)	91.0 ± 9.7[a] (300)
Prefreezing motility (%)	64.8 ± 9.10[a] (581)	60.6 ± 2.6[a] (151)
Postfreezing motility (%)	26.3 ± 3.20[a] (636)	27.2 ± 4.4[a] (260)
Incidence of ejaculation with initial motility less than 50 (%)	6.7[b]	32.0[a]
Total sperm output (vol x conc.)	253.0 ± 23.3[a]	191.8 ± 28.0[b]
Total quality semen (vol. x conc. x mot.)	156.9 ± 23.0[a]	98.1 ± 17.5[b]

[a,b] Means in the same row with different superscripts differ ($P < 0.05$); Number in parenthesis represents number of ejaculates

Table 9. Mean semen characteristics of Murrah buffalo (MB) and crossbred (CB) bulls of the same semen age group (three to four years old), nutrition, management, and semen collection frequencies

Breed	Ejaculate	N	Volume (ml)	pH	Initial motility (%)	Sperm conc. 10^7m/ml	Motility after dilution (%)	Postfreezing motility (%)
MB	I	12	2.55	6.79	64.58	93.17	64.58	31.25
	II	4	2.42	6.72	61.25	64.00	62.50	30.00
	Average	16	2.48	6.75	62.92	78.58	63.54	30.62
CB	I	14	2.33	6.74	60.71	72.57	61.43	28.67
	II	10	1.79	6.74	61.50	73.50	61.50	31.86
	Average	24	2.06	6.74	61.10	73.04	61.46	30.72

Table 10. Effect of freezing procedure on percent change in motility, abnormal sperm, and dead sperm of Philippine carabaos (PC), crossbreds (CB), and Murrah buffaloes (MB) during the first 30 days of storage at -196ºC

Parameter	PC	CB	MB
Motility	0	-6.0	-5.5
Abnormal sperm	0.21	0.40	4.3
Dead sperm	0.07	0.20	2.0

Table 11. First service pregnancy rate of Philippine carabaos artificially inseminated with frozen semen of Murrah buffalo or crossbred (F_1)

Breed	N	Pregnant	% Pregnancy
Murrah	647	233	36.0
F_1 (MB x PC)	122	43	36.2

germplasm are conserved for long-term genetic improvement program. The general premise is that through the years, domestic stocks of swamp buffaloes have adapted to the local conditions and therefore there are certain genes that can be very useful for future breeding and genetic improvement. Gene pools for the Philippine carabao were established in the three main islands of Luzon, Visayas and Mindanao. The animals are kept as Open Nucleus Herds (ONH), and selection of better stocks from the surrounding communities is done on a continuing basis. Selected animals outside of institution herd are taken in and shall form part of the ONH for the Philippine carabao. These animals have been chosen primarily for size and reproduction ability.

There is also a Carabao sanctuary in a separate island that is so well protected from the introduction of any exotic germplasm of buffalo of any form. Farmers are utilizing the indigenous buffaloes for their farming activities and this will certainly be carried through for many generations to come.

Gene pool for riverine buffalo for meat improvement – "American Murrah" that had been imported into the country and raised as a herd in a facility located at PCC at Ubay Stock Farm, Ubay, Bohol (Visayas), ensure availability of superior germplasm for improvement of the carabao's meat production abilities. In this facility, riverine buffaloes are selected for growth and reproduction abilities, with consideration for meat quality characteristics. Bulls and semen of outstanding genetics are readily available to farmers interested in raising buffalo for meat.

Gene pool for improvement for milk production – Elite herds of "Bulgarian Murrah" are reared at the National Riverine Buffalo Gene Pool and at two separate institutions in southern islands. Animals with outstanding performance at the farmer cooperatives are also enrolled as part of the gene pool. With organized selection and testing system in place, the country is now ensured of sustained sources of genetic materials for improvement for milk production. The system can produce about 400 bulls of good quality per year, with the top ranking bulls subjected to organized progeny testing and then assigned as semen donors for use in the nationwide AI program, while the above average bulls are used in the wide-scale bull loan for crossbreeding in the villages.

Embryo biotechnology laboratory – Attempts to hasten the envisaged genetic improvement has also led to the development of facilities and reproductive biotechniques that can be used as important tools in some specific areas not normally achieved through the traditional breeding techniques. To date, the facilities established at the PCC Central Research Station and in the satellite laboratory in Maharastra, India have developed technologies to produce high genetics embryos through the *in vitro* system. These efforts are complemented with the ovum pick-up procedures, obtaining oocytes from superior donors for IVM/IVF as an alternative option to superovulation scheme that proved to be less predictable and more expensive. Likewise, the facility has just embarked on attempts to propagate superior genetics dairy buffaloes through the use of somatic cell nuclear transfer technique (SCNT).

There are only two countries with substantial population of swamp buffaloes are engaged in widescale crossing and backcrossing with riverine buffaloes namely China, and the Philippines. In 1986, initially from manipulating ovarian function to achieve superovulatory response related to the envisaged embryo transfer technology. In 1991, the first calf out of a Philippine carabao surrogate dam (2n=48) derived from *in-vivo* embryo production from a riverine donor (2n=50) was born out of the non-surgical transfer. This particular research work also demonstrated the possibility of harnessing the local animals as surrogates of riverine buffalo embryos for enhanced genetic improvement.

In view of the poor results obtained from superovulation treatments of various hormone regimens, it was decided that research be diverted to *in-vitro* embryo production techniques. Thus in 1996, the first IVM/IVF-derived calves in the country were born out of the PCC scientists' research efforts.

Having achieved some degree of confidence on the IVM/IVF procedures, research on reproductive bio-techniques grew, with PCARRD-DOST supporting a project aimed at establishing a satellite embryo biotechnology laboratory in India in order to harness the dairy buffalo genetics in the form of ovaries out of Indian slaughterhouses. As a complementary technique, the PCC research team developed the simplified vitrification technique for freezing buffalo embryos. Thus, in March 2001, three months after the establishment of the satellite laboratory in India, the first batch of IVM/IVF vitrified embryos were transported to the Philippines. The first calf from such technique was delivered by local surrogate dam on April 5, 2002.

Currently, efforts are also directed towards refining the ovum-pick-up technique as a complementary technique like IVM/IVF. More recently, scientists at PCC have initiated somatic cell nuclear transfer technique (SCNT) in attempts to replicate "super buffalo".

Genetic improvement efforts. Breeding research that aims to improve the milk production potential of the riverine buffalo population in the country is carried out by putting in place a system of ranking and selecting the best animals. This is done by developing a BLUP animal model for determining the genetic merit of individual animals with milk production record. Initially, evaluation of cows was based solely on milk volume alone, but starting in 2005, milk fat and protein percentages are included as additional traits in the evaluation. The model for genetic evaluation, including the software, is developed in collaboration with the geneticists of the Animal Genetics and Breeding Unit (AGBU) and the Agri-Business Research Institute (ABRI) of the University of New England in Armidale, Australia funded by ACIAR. The model is expected to produce as much as five estimated breeding values (EBVs). The first lactation is divided into first, second and third trimester with corresponding EBV. This gives a total for five EBVs combined to a single index to rank the cows and bulls. The same also holds true for milk fat and protein percentages as these are considered separate traits.

Gene bank – Genetic materials in the form of frozen semen, embryos and tissues are also collected from distinctly different breed groups and lines as well as from outstanding animals in the gene pools and are cyropreserved and stored in the gene bank.

Included in the gene bank are tissue samples collected from other animals within the buffalo family, the Tamaraw (2n = 46), an animal that is classified as endangered species and is found only in the Philippines.

Expanding usage of superior germplasm

The utility of superior genetics obtained from the sustained selection and testing efforts is expanded by using females as dams of future sires while proven sires are used for AI. Outstanding sires tested and selected from the gene pool have been fully harnessed as semen donors in order to cover as many carabaos possible to effect the desired genetic improvement. Component activities/strategies on how to expand usage of superior genetics are as follows:

Semen processing laboratory − In support of genetic improvement efforts, the country has established semen processing facilities as early as 1984, and to date, such facility houses 40 donor and 15 junior bulls for testing. Frozen semen from progeny-tested bulls are produced at a quantity more than sufficient to meet the national requirements, including the needs of the technicians of all local government units (LGUs), non-government associations (NGAs) and private AI technicians.

Intensified artificial insemination and bull loan program − In cooperation with the LGUs, crossbreeding of native buffaloes with the dairy breed to improve the genetic potentials for milk is carried out nationwide. This system has current annual coverage of about 55,000 head.

In the past two years, efforts were directed to privatizing the AI services by developing village-based private technicians. Based on the data so far, these private AI technicians are more cost efficient and are more responsive in many respects compared to LGU technicians. Their main advantage is their all-time presence right in the village service area and their "pay-per-service" system that releases the government from costly subsidies in the form of salaries and allowance. Under a condition where animal ownership per farmer is only 1 to 3, and that the households are scattered widely in the rural communities, it appears that harnessing village-based AI technicians offer many advantages.

The AI is augmented with program of bull loan which is undertaken in villages where AI services are not available. In fact, even in some areas where AI services are accessible, many farmers have high preference for natural mating, owing to very good success rate in this method compared to AI. On the average, the national AI system has only registered a success rate of 30.0% first service. Subsequent services of course can result in higher percentage of calves on the ground, but such higher rate is obtained in single service under natural mating. A system of incentive is offered to farmers tending breeding bulls in the village, that of full ownership of the bull once the bull has sired at least 50 calves. Many farmers get their bull ownership in just a period of 2 years.

Technical support to LGU technicians – To enhance the AI and crossbreeding program, technicians of the LGUs around the country are trained and are provided with support for expanded AI services. To date, there are about 1,500 active AI technicians serving the large ruminants throughout the country. Most of these technicians are with the local government units and some are private village-based technicians. As a way of government subsidy to the genetic improvement program, frozen buffalo semen are provided free of charge up until now. However, as the scheme to privatize the AI services is gaining acceptance, frozen semen are provided to private AI technicians at cost. Provision of liquid nitrogen to preserve quality of frozen semen is at the shared account of national and local governments, but will likely be provided at a later stage at cost to private technicians who, in turn, charges for their services.

Support to establishment of buffalo-based enterprises

Two approaches are being introduced in areas considered to be impact zones for the project. These areas are considered as such in view of the density of breeder stocks in the community and their potential for the establishment of buffalo-based enterprises, closeness to market being a major consideration. In these communities, massive AI services are carried out with the intent of producing critical number of crossbreds, which are potential dairy animals. While this activity covers many animal raisers, the process is relatively slow owing to the long gestation of buffaloes and their late maturity. As a way of "shortcutting" the process, incubator modules composed of purebred buffaloes are introduced in the impact areas. These modules serve as show window for the farmers to see and appreciate the benefits of rearing the correct animal and adopting the proper management and breeding practices. In the impact areas, carabao raisers have been organized into cooperatives to collect, process and market milk and milk products in a systematic manner. Support to these cooperatives takes the form of organizational as well as technical trainings and the provision of post-production equipment, mostly to preserve the quality of the milk.

In the National Impact Zone (Nueva Ecija), primary cooperatives involving thousands of families have formed into Nueva Ecija Federation of Dairy

Carabao Cooperatives (NEFEDCCO) to supply milk and dairy products to major urban markets.

In the 13 regions, there are about 44 primary cooperatives, which, collectively, can produce the same milk volume and value of milk as in the National Impact Area.

There are also thousands of crossbreeds in the AI target villages and can likewise become potential sources of milk and meat products. Community organization, training and support to entrepreneurship are to be intensified in order to harness their potentials.

CONCLUSION

The future will see sustained and more intensive efforts to pursue the goal of transforming genetically the traditionally draft animal to producer of milk and meat and eventual establishment of viable and progressive buffalo-based enterprises. Major strategies and activities to achieve the long-term objectives are the following:

Intensive crossbreeding and continuous backcrossing for dairy herd build-up – The current AI and natural mating services covering only about 6.6% of the total breedable female in the population will have to be expanded to about of 15.0% in the next five years and to 30.0% by 2016. This increase in coverage will rely heavily on the recruitment and training of more village-based private AI technicians that complements the existing technicians of the local government units (LGUs) plus the deployment of about 500 new selected bulls annually in areas not covered by AI services. During the span of next 10 years, the F1 crossbreds produced out of swamp and riverine buffalo crossing will be subjected to backcrossing with the purebred riverine parents to produce buffaloes with increasing bloodlines of dairy breed. Such backcrossing will be carried out for at least three generations to produce animals with minimum of about 87.5% riverine blood.

Of course, during this period of extensive crossing and backcrossing, there will also be a sustained effort to maintain gene pool of the indigenous water buffalo breed.

Sustained genetic improvement program (GIP) – System for selection and testing of genetically superior animals for milk as applied to the current institutional purebred population of buffaloes shall be expanded and intensified to include the many herds outside of the institution. Evaluation of animals and establishment of EBVs using milk volume and milk constituents as parameters for selection shall therefore be sustained. This continuing endeavor ensures that animals in the program shall have genetic improvement generation after generation.

Outsourcing of fresh genetics in various forms, such as live animals, semen, embryos and tissues, shall be a component strategy in order to enhance genetic improvement.

Some specialized system may be established for meat production in the future, and this being the case, selection and testing of the future sires for growth and meat characteristics will be of importance. Indeed, the very recent data obtained from studies in the Philippines comparing preference for meat of buffalo vs. cattle suggests that A & B consumers have tendency to favor buffalo meat. Molecular studies of meat properties related to tenderness pointed out that there are basis for this preference.

Intensified use of biotechniques as a tool for genetic improvement – As can be gleamed from the latest studies in bovine, the use of recently developed biotechnologies, such as marker-assisted-selection (MAS), has provided adequate opportunities to enhance selection and thus genetic improvement. This area will therefore receive considerable attention in the future.

In similar manner, the proper usage of reproductive biotechniques, such as ovum pick-up and *in vitro* fertilization techniques, is likely to be refined for buffaloes and can aid in enhancing the propagation of superior animals. This can also be complemented with the development of somatic cell nuclear transfer technique (SCNT), which has yet to achieve a level of acceptable efficiency to be of practical use.

Social organization and support to expansion of post-production and market-related activities for milk and meat – In the many communities with increasing number of crossbred and purebred dairy buffaloes, there shall be intensification of community organizing efforts with the aim of mobilizing the smallholder farmers into formation of primary dairy producers and cooperatives. This is very essential initial step towards establishing a workable milk collection scheme that is very important for marketing these highly perishable products. Also, provision of technical training on production and post-production are rendered easy with organized farmers in the communities.

In strategic points, milk collection centers with handling and cooling facilities for milk are indispensable as volume of milk from the primary cooperatives increases. But along this provision, systems of quality test for milk as well as appropriate payment scheme need to be established. As the number of primaries increases, so does the volume of daily milk collection, and thus there is a necessity of creating a marketing arm to meet the requirements for processing, packaging and distribution of the various milk and dairy products reaching the commercial market.

Male crossbreds are also to be produced in good numbers out of the massive crossbreeding nationwide. However, since the animal ownership is small but widely spread geographically, a system of consolidation, fattening, slaughtering, carcass fabrication, handling and distribution has to be organized in strategic locations.

REFERENCES

ABAS, M.O. 2006. Current status and challenges in buffalo production in Malaysia. Proc. International Seminar on Artificial Reproductive Biotechnology for Buffaloes. FFTC-RIAP, Bogor, Indonesia.

BARKER, J.S.F., T.K. MUKHERJEE, M. HILMI, S.G. TAN and O.S. SELVARAJ. 1991. Genetic identification of strains and genotypes of swamp buffalo and of goats in Southeast Asia: Rationale for their study. Proc. of a Seminar, Kuala Lumpur, Malaysia, 10 – 14 February,1991

BONGSO, T.A. M. HILMI and P.K. BASRUR. 1983. Testicular cells in hybrid water buffaloes (*Bubalus bubalis*). Res. Vet. Sci. 35(3): 253 – 258.

DAI, K., C.B. GILLIES, A.E. DOLLIN and M. HILMI. 1994. Synaptonemal complex analysis of hybrid and purebred water buffaloes (*Bubalus bubalis*). Hereditas 121: 171 – 184.

FAO. 2007. FAOSTAT, FAO Statistics Division 2009; 2009 World Population Data Sheet. Production Yearbook, 2007.

FAO. 2009. FAO Food Outlook, June 2009.

FAYLON, P.S. 1992. Carabao Development in the Philippines. *In:* Carabao Production in the Philippines, FAO/UNDP PHI/86/005. Field Doc. 13. pp. 1 – 23.

HARISAH, M., T.I. AZMI, M. HILMI, M.K. VIDYADARAN, T.A. BONGSO and Z.M. NAVA. 1989. Identification of crossbred buffalo genotypes and their chromosome segregation patterns. Genome 32(6): 999 – 1002.

HUANG, Y. 2006. The chromosome polymorphism in crosses from riverine x swamp buffalo. Proc. 5th Asian Buffalo Congress, Nanning, China. pp. 70 – 75.

LEMCKE, B. 2004. Production if specialized quality meat products from water buffalo: Tender buff. Proc. 7th World Buffalo Congress, Manila, Philippines. I: 49 – 54.

NABHEERON, P., V.G. MOMONGAN, O.A. PALAD, S.S. CAPITAN, A.S. SARABIA, R. OBSIOMA, A.N. DEL BARRIO, R.M. LAPITAN, E.C. DELA PENA and Z.M. NAVA. 1991. Conception rates of the Philippine carabao inseminated with buffalo frozen semen under smallholder farmer condition. Abstract of Researchs on the Philippine Water Buffalo, Reproduction, Paper R-26.

SITUMORANG, P and P. SITEPU 1991. Comparative growth performance, semen quality and draught capacity of the Indonesian swamp buffalo and its crosses. ACIAR Proc. No. 34 :102 – 112.

YANG, B. and C. ZHANG. 2006. Buffalo crossbreeding in China: Past and current situation with future prospects. Asian Buffalo Magazine pp. 4 – 10.

YANG, B., X. LIANG, X. ZHANG, C. ZOU and F. HUANG. 2004. Status of buffalo production in China. Proc. 7th World Buffalo Congress. Manila, Philippines. II: 513 – 518.

YANG, B., Y.L.Q. ZENG, J. QUIN and C. YANG. 2007. Dairy buffalo breeding in the countryside of China. Italian J. Anim. Sci. Vol. 6. supp 2, pp. 25 – 29.

ZHANG, C. 2006. The model of Chinese buffalo breeding. Proc. 5th Asian Buffalo Congress, Nanning, China. pp. 166 – 185.