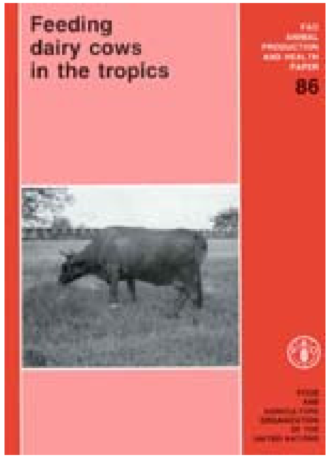
FAO ANIMAL PRODUCTION AND HEALTH PAPER 86



Feeding dairy cows in the tropics

Proceedings of the FAO Expert Consultation
held in Bangkok, Thailand
7–11 July 1989

Edited by
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(*) These authors were unable to participate in the meeting.However their paper is included as a valuable contribution tothese proceedings.

INTRODUCTION

The FAO Expert Consultation on Feeding Dairy Cows in the Tropics was held in Thailand in the FAO Regional Office for Asia and the Pacific in Bangkok, from 3 to 7 July 1989.

Recent FAO statistics show that, while milking the same number of cows (about 110 million head) the developing countries (mainly located in the tropical zone) produce only 22 % of the whole fresh milk equivalent produced by the developed countries and 18 % of the total world production (461.5 million t). In addition, milk production in Asia and to a lesser extent in Africa was reduced from 1986 to 1987 due to drought and the policy measures taken by some countries. In spite of successful achievements such as “Operation Flood” in India, many failures have also been observed in the past.

The problems encountered in stimulating milk production in developing countries are very complex. As in other agricultural development operations many difficulties such as pricing, marketing, etc are beyond the control of the producer. However, technical constraints including nutrition, health and breeding, have still to be, and can be overcome.

Among these constraints the nutrition aspect is probably the first factor limiting milk production. The 1987 Conference of FAO drew attention to the increasing difficulty in providing the bulk of feed requirements for cattle through grazing, crop by-products and to a lesser extent, fodder crops.

Recent advances in the knowledge of ruminant nutrition physiology and in the nutritive value and techniques of utilization of feed resources including unconventional ones e.g. crop residues and agro-industrial by-products, provide scope for overcoming the forecasted feed shortage.

The purpose of this expert consultation therefore was to:

- review the various milk production systems in the tropical areas (humid and dry) according to agro-climatic and technical, economical and sociological conditions including special situations like peri-urban production systems;

- review new knowledge in ruminant digestion nutrition and physiology and consider ways and means of implementing rational feeding systems that could overcome, at the lowest cost, nutritional constraints which hamper milk production and herd productivity in the various prevailing systems;

- match milk production (specialized or dual purpose) systems to available and potential feed resources, taking into account their nutritional characteristics, and considering both subsistence and commercial systems;

- make recommendations for the development of sustainable milk production systems based on locally available feed resources

The opening speech was delivered by Mr. Vitoon Kamnirdpeth, Director General of the Department of Livestock Development, on behalf of the Royal Government of Thailand. First of all he expressed his government's appreciation to FAO for organizing this Expert Consultation in Thailand, and welcomed all the participants. He briefly reminded the Experts of the milk production history in Thailand which started only 30 years ago and has developed rapidly during the last ten years. Although milk production is increasing, milk consumption per caput is still low and the Government is trying to encourage the Thai population to consume more milk and milk products. He pointed out that the main problems that the dairy farmers encounter in Thailand are similar to those encountered in other tropical developing countries, particularly those concerning animal feeding but also breeding, health, etc.… This Expert Consultation will deal with the feeding of dairy cattle. It should be a good opportunity within this context to help increase milk production in tropical developing countries.

The welcome address was given by Mr. S.S. Puri, Assistant Director-General and FAO Representative for Asia and the Pacific. He first pointed out that the Expert Consultation would not only deal with dairy cows but also with buffaloes which are very important in Asia, especially in India where they are more numerous than cows. He mentioned that in Asia human diet is mainly dependent on rice/cereals which implies an unbalanced diet. Thus, in terms of non-cereal food diet, there is a need for increasing milk and meat production and availability. About 40 % of the number of cows in the world are in Asia, but they are only responsible for about 7 % of the world milk production. The productivity of the animals is low and did not follow the rapid increase of cereal yield in the last 20 years. For these reasons, diets are still deficient in good quality proteins and particularly those from milk and milk products. He also pointed out that in the tropical areas, there is very little land still available for pastures. For example, in India 96 % of the usable land is already cultivated. There is a need to increase feed in quantity and quality for milk production. Therefore this Expert Consultation on feeding is of great importance.

Technical secretaries were R. Sansoucy and P. Hassoun

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MEDIUM-TERM OUTLOOK FOR DAIRYING IN THE DEVELOPING COUNTRIES

by

W. Krostitz

INTERNATIONAL BACKGROUND

Milk production and consumption have so far been concentrated in the developed regions - mainly

Europe, the USSR, North America and Australasia - though more recently Japan has also become an important milk consuming and producing country. In contrast, the developing countries, with about three quarters of world population, account for just one quarter of world milk output and, as net imports have risen, for slightly over a quarter of global consumption of milk and milk products. However, since the 1970s, when their share was only one-fifth, milk production in the developing countries has grown faster than in the developed regions.

This difference in production and consumption trends between the two categories of countries is likely to accentuate in the medium term. As indicated in Table 1, the developing countries' share of global milk production could reach nearly a third by the end of the century. Yet, as their population is projected to increase to 4.8 billion, or four-fifths of the world total, while their net imports of dairy products will probably decrease, average availability, at just over 40 kg of milk equivalent, will not be significantly higher than at present and will be still merely one-seventh of the average level for the developed regions. Moreover, this relatively low statistical average will conceal wide differences between individual countries and, within countries, among income groups. Perhaps even more than in the past, consumption of milk and milk products in the developing regions will be concentrated among middle and high-income groups in urban areas. However, dairy development could increasingly support efforts to improve rural incomes and living standards in developing countries with a reasonable potential for milk production.

The difference in likely future rates of growth in milk production between developing and developed countries reflects not only trends in demand but also recent changes in production policies. In the developed market economies, with the major exception of Japan, per caput demand for milk and milk products overall seems to have reached saturation point, while population growth is slow. In some Eastern European countries and the USSR there would appear to be scope for rises in demand for the long run, but the medium-term outlook is for stagnating or even falling consumption owing to the effects on consumer prices and incomes of structural adjustment programmes. Moreover, with non-food use, particularly feed use, decreasing average availability per head of population in the developed countries as a whole is expected to fall by the end of the century.

Large-scale, heavily subsidized use of milk and milk products in livestock feeding was one of the main features of surplus disposal in the developed market economies over the past quarter century when milk output increasingly exceeded effective demand. On average during the 1980s, governments of West European and North American countries subsidized the feed use of some 20 million tons of milk equivalent per year, most of it in the form of skim milk and skim milk powder but occasionally also butter, with the EEC accounting for the bulk of this. At the same time, West Europe and North America exported large quantities of milk products, at reduced prices, or as food aid. Thus, by the first half of the 1980s, almost 20 million tons of milk equivalent annually or three-quarters of world exports of dairy products were heavily subsidized. Confronted by this situation, low-cost producers of traditional exporting countries in Australasia were hardly able to maintain the volume of their sales abroad, despite a growing international market, while most suppliers among developing countries had to withdraw from export marketing. At the same time, net imports of the developing countries, of which nearly 20 percent was food aid, reached about one-eighth of their total consumption as can be seen from the table.

Table 1. WORLD DAIRY SITUATION AT A GLANCE - PAST AND PROJECTED

	Milk production	**Net imports 1**	**Availability** [1] [2]	
			Total	**Per caput**
	(------------------------------------(million tons)		**---------------------------------------)**	**kg**
World total				
1974–76	422	-	422	106
1986–88	521	-	521	104
2000	585	-	585	95

Developed countries				
1974–76	335	-8	327	292
1986–88	388	-20	368	300
2000	400	-15	385	290
Developing countries				
1974–76	87	8	95	32
1986–88	136	20	156	41
2000	185	15	200	42

[1] Milk and milk products in milk equivalent.

[2] Including non-food use and waste.

Ample availabilities of relatively cheap, or entirely free, milk products in international markets supported policies aimed at low consumer prices in many developing countries which in turn discouraged the development of local milk production. As a matter of fact, in a situation of almost chronically depressed prices in international trade, the comparative advantage of milk production in developing countries was generally considered to be low. This was true not only of the lending policies of national and multilateral development banks but also of the investment policies of transnational companies. Although such companies made considerable investments in milk processing and distribution throughout the developing regions, their interest in the development of local milk production lessened in view of the cheap raw material supplies in international markets that could be drawn upon for recombining. Among the few developing countries which, notwithstanding this discouraging background, launched policies of strong support to domestic dairying as early as in the 1960s and 1970s were India, the Republic of Korea, China, Cuba and, to a certain extent, Venezuela. As in India, dairy

development programmes in Cuba and China have benefited substantially from food aid in the form of milk powder and butter oil which after recombining have been sold in the urban markets at prices equivalent to those obtained by domestic producers. While adding to local milk supplies, the main purpose of such commodity aid has been to generate funds for investment into the development of local milk production and marketing.

WORLD STOCKS AND EEC SURPLUSES

However, during the second half of the 1980s, the international dairy situation changed significantly. The EEC, faced with ever rising costs of its farm support policy, introduced quotas on the marketing of cow's milk in 1984/85 and has since then reduced output by about 10 million tons, or one tenth. Other West European countries and Canada have operated similar supply management schemes. The United States has repeatedly cut the milk support price, accompanied by direct measures to reduce the dairy cattle population. In addition, dairying in New Zealand was affected by adverse weather. Helped by huge sales of butter at cut-rate prices mainly to the USSR, world stocks of dairy products were reduced to rather low levels by 1989, while prices in international trade in dairy products rose sharply. On the basis of c.i.f. prices of skim milk powder and butter oil prevailing during the first half of 1989, the cost of raw material for the recombining of 1 tonne of milk with 3 percent fat was about US$260, almost three times as much as during the mid-1980s. At this level of international prices the competitive advantage of imports over local dairy products had practically disappeared in countries with a reasonable potential for dairying. As discussed in a second paper submitted by FAO's Commodities and Trade Division to this seminar, prices in international dairy products trade have decreased again in 1989/90 though they remain well above the levels registered in the middle of the 1980s.

Milk production in Western Europe and, to a lesser extent, North America still exceeds effective

demand. Hence, access to their markets will remain restricted and some subsidization of their domestic consumption and exports is likely to continue. However, unless present production controls in these two regions are significantly relaxed surpluses should remain manageable and prices in international dairy trade would not return to the very depressed levels of the mid-1980s. [1]

EFFECTS OF HIGHER INTERNATIONAL PRICES ON DEVELOPING COUNTRY IMPORTS

In the USSR, Eastern Europe and the developing countries which account for the bulk of world imports of dairy products, self-sufficiency ratios will probably increase in the medium term. Higher international prices and continued foreign exchange constraints seem to have discouraged imports by the USSR and some East European countries and encouraged exports by others. For similar reasons, many developing countries have reduced imports, while several low cost producing developing countries may expand or resume exports of dairy products.

In Argentina, Uruguay and southern Chile milk production costs, at about US$100 per tonne, are among the lowest in the world. Although shipments are small compared with those of the big suppliers in Europe, North America and Oceania, Uruguay has in recent years been the largest net exporter of dairy products among the developing countries. Given supportive government policy, Argentina could regain its position as the leading exporter of dairy products among developing countries. Once a significant supplier of butter, cheese and preserved milk products, Argentina's dairy industry has reduced its sales abroad over the past two decades, when the fall in export returns was compounded by taxes imposed by government on shipments to foreign markets. Elsewhere in Latin America, Costa Rica has recently begun to offer milk powder in external markets as rising prices have stimulated milk output and, reinforced by recession, curbed domestic demand for milk and milk products. In the longer run, Nicaragua might become an exporter of milk powder again, having been a net

importer of dairy products throughout the 1980s.

In Africa, Zimbabwe and Kenya are re-emerging in their traditional role as net exporters, mainly of milk powder and butter to neighbouring countries in southern Africa and the Near East. In the markets of the Near East oil countries, Turkey also hopes to be able to sell rising quantities of cheese and other milk products, and there could be interest in certain milk specialities from South Asia. China and Mongolia might increase sales to the eastern parts of the USSR, a number of developing countries in East and South East Asia and perhaps to Japan.[2]

[1] Assuming continued restrictive production policies in West Europe and North America, dairy farmers in Oceania will probably feel encouraged to raise production for export though this is not likely to offset the reduction in West European and North American supplies. Japan, the only OECD country whose imports of dairy products could grow over the medium term, might absorb part of higher Oceanian supplies.

FUTURE PROSPECTS

In the short term the response of existing and potential suppliers to higher international prices, both in the developing regions and in Oceania and East Europe, could be through reducing domestic consumption rather than raising production. The long depression in international prices has discouraged investment into dairy farming in many low-cost producing countries, reinforced by general economic and financial difficulties including high interest rates and shortage of foreign exchange. Because of the large amounts of capital and time required to raise milk production and processing, future prospects for dairy products exports are apparently assessed with caution.

In fact, the largest part of the projected increase in milk production of the developing countries

is likely to be for domestic consumption and, as a group, the developing countries will probably continue to have a sizeable net import, as indicated in the table. Imports will be increasingly concentrated in the petroleum exporting countries of Asia, North Africa and Latin America but, unless oil prices rise, even these countries may not maintain the volume of their imports at recent levels. Moreover, some of them, such as Saudi Arabia, have for some time promoted local milk production though in such areas dairying is costly, and a country's dependence on imported dairy products may just be replaced by dependence on feeds and other inputs. Dairying based on imported feeds will therefore be the exception rather than the rule in a situation where many developing countries are heavily indebted and short of foreign exchange.

DEMAND AND PRODUCTION IN ASIA

One country which has been able to afford a rapid expansion not only of its milk but also of its meat and egg production largely based on imported feeds is the Republic of Korea. In recent years this country has purchased between 7 and 8 million tons annually of feed grains and other concentrate feeds at a cost of roughly US$ one billion. In addition, the Republic of Korea where milk production was virtually unknown until the 1960s but reached 0.5 million tons in 1980 and over one million tons in 1985, based its dairy development programme essentially on imported dairy cattle. The Korea Rural Economic Institute projects milk production to rise to 1.5 million tons by the early 1990s and nearly 3 million tons by the beginning of the next century. While expensive in terms of foreign exchange and to final consumers, milk production has been profitable to farmers who have specialized in this activity or added dairying to their enterprise. The Republic of Korea, though not providing a model of dairy development which would be suitable for the majority of developing countries, illustrates the change in food consumption habits as a result of rapid economic growth and urbanization. Unlike most other developing regions, East Asia has no tradition of milk consumption. If the above projections materialize, per caput consumption of milk and milk products in the Republic of Korea which

was virtually nil before 1970, would reach over 30 kg of milk equivalent in the early 1990s and over 50 kg by the turn of the century. However, notwithstanding its sizeable balance of trade surplus, the country is becoming preoccupied about its dependence on imported feed and is now paying greater attention to the development of domestic fodder resources.

2 In the longer term a general liberalisation of agricultural markets and trade as a result of the GATT's Uruguay Round would of course greatly improve the prospects for exports from low-cost producing countries such as Uruguay, Argentina, New Zealand or Australia. However, at this stage it would appear to be premature to talk about possible implications of any agreements reached under the Uruguay Round.

China is another example of rapidly rising demand for and production of milk as a result of social and economic change. Traditionally the majority of Chinese did not consume milk, but since the late 1970s demand for milk and milk products has experienced a fast rise in urban areas around which modern dairying based on high yielding Chinese Black and White cattle (largely Holstein-Friesian blood) and, to a lesser extent goats, is being promoted. By 1992 Chinese plans call for an increase in per caput consumption of milk from 3 to 5 kg. With most milk consumed by the urban fourth of the population, average intake in urban areas would thus reach some 20 kg at the beginning of the next decade. Milk production in China has risen at double-digit rates during the past decade but was still less than 4 million tons in the late 1980s. Original plans which indicated a target of 30 million tons by the year 2000 have been revised downwards as feed supply is lagging behind the requirements of the livestock sector.

In South East Asia imported milk products became popular among urban consumers after the Second World War, but local milk production is a more recent phenomenon, with Indonesia and Thailand experiencing the most rapid growth. As in China, dairy development in these two countries is based on domestic feed and cattle of European or North American origin and

crossbreeds. However, whereas China shifted emphasis from dairying on large-scale state or collective farms to milk production by smallholders in the 1980s, Thailand and Indonesia have right from the start given priority to smallholder dairying within their rural development policies.

The same has been true of India, the biggest milk producer among developing countries, where milk output is projected to rise by some 40 percent to 61 million tons by 1995 with per caput consumption increasing from its present level of 58 kg per year to about 68 kg. Under the project “Operation Flood”, the world's largest dairy development project, a resource-conscious policy of production largely based on local feeds and indigenous cattle and buffaloes and accompanied by efficient marketing of milk and milk products has benefited both rural producers, especially small-holders, and urban consumers. The success of this project, not only from a technical but also from a socio-economic viewpoint, has in the meantime aroused increasing interest in dairy and agricultural development planning throughout the developing countries.

As in South Asia, milk production and consumption has a long tradition in West Asia and most parts of Africa and Latin America. However, in the latter three regions prospects for dairy development appear to be less favourable than in South and East Asia. This reflects not so much natural resource endowment but rather the outlook for general economic development. During the remainder of the century, economic growth and rises in incomes are likely to be considerably higher in the eastern and southern parts of Asia than in the other developing regions. Hence, as in the recent past, strong consumer demand is likely to be a major stimulus to dairying in southern and eastern Asia, an area which will comprise almost half of the world's population by the turn of the century.

THE FUTURE FOR MILK IN DEVELOPING COUNTRIES

However, although milk production is a relatively efficient way of converting vegetable material into animal food and dairy cows, buffaloes, goat and sheep can eat fodder and crop by-products which are not eaten by humans, the loss of nutrients involved in production and the large amounts, often imported, of energy and equipment required in milk handling inevitably make milk a comparatively expensive food. Also, if dairying is to play its part in rural development policies, the price to milk producers has to be remunerative. In a situation of increased international prices, low availabilities of food aid and foreign exchange constraints, large-scale subsidisation of milk consumption will be difficult in the majority of developing countries. Hence, in the foreseeable future, milk and milk products in the majority of developing countries will not play the same role in nutrition as in the affluent societies of developed countries. Effective demand will come mainly from middle and high income consumers in urban areas.

There are of course ways to mitigate the effects of unequal distribution of incomes. In Cuba where the government attaches high priority to milk in its food and nutrition policy, all pre-school children, urban and rural alike, receive a daily ration of almost a litre of milk at a reduced price, and cheap milk and milk products are made available to certain other vulnerable groups, while milk products outside the rationing system are sold at a price which is well above cost level. Until recently most fresh milk in the big cities of China was reserved for infants and hospitals, but with the increase in supply rationing has been relaxed. In other countries dairy industries have attempted to reach lower income consumers by variation of compositional quality or packaging and distribution methods or blending milk and vegetable ingredients in formula foods for vulnerable groups. For instance, pricing of products rich in butter fat or in more luxury packaging above cost level so as to enable sales of high protein milk products at a somewhat reduced price has been widely practised in developing countries.

THE LACTATING COW IN THE VARIOUS ECOSYSTEMS: ENVIRONMENTAL EFFECTS ON ITS PRODUCTIVITY

by

H.D. Johnson

CLIMATES OF THE WORLD

Milk yields are a product of animal genetic and environmental interactions. Milk yield for a specific genotype, especially in tropical environments or ecosystems, is a function of climate and its interactive influences on the quantity and quality of feed, the presence of disease and parasites and the utilization of technology to alleviate nutritional, thermal and health limitations. Each climate zone and/or ecosystem includes variations in the environmental complex which influences milk yields and dairying practices in the tropics. Zones of the world between the Tropics of Cancer and Capricorn include the majority of the cattle and buffalo of the world and the climate in these regions is especially limiting to milk yields, growth and reproduction when both the temperature and humidity is high.

Emphasis in this paper will be on the thermal or direct climatic aspects of the environmental factors as they influence the cows ability to eat, maintain heat balance, produce milk and reproduce. Of the meteorological factors (temperature, humidity, wind, radiation, photoperiod

and rainfall), the temperature and humidity (including rainfall) are the limiting factors most difficult to alleviate.

Figure 1 presents the average monthly temperature-humidity-index (THI) for numerous temperate zones and tropical countries. Generally, the climate of the countries in the left section, depending on the numbers of months above 72 THI, does not preclude the use of Holstein dairy cows. However, the introduction of Holsteins into the countries on the right section (humid tropics) results in moderate to severe limitations in milk yield due largely to the temperature/humidity and related nutritional factors. Adaptable but lower yielding indigenous cattle have been used for centuries as a source of meat, milk and fibre in the tropical zones.

Figure 2 is an illustration of these calculations showing the number of months throughout the year that THIs were greater than 72 (B). THI average of months above 72 (C), which is a multiple of A × B, best expresses the comfort or adversity of climate zones. The annual THI average also reflects the relative limitation of the various climate zones of the world for dairy cows (Figure 3). Table 1 lists these indices which express the adversity or comfort as indicated by Columns A, B, C and D.

Figure 1.

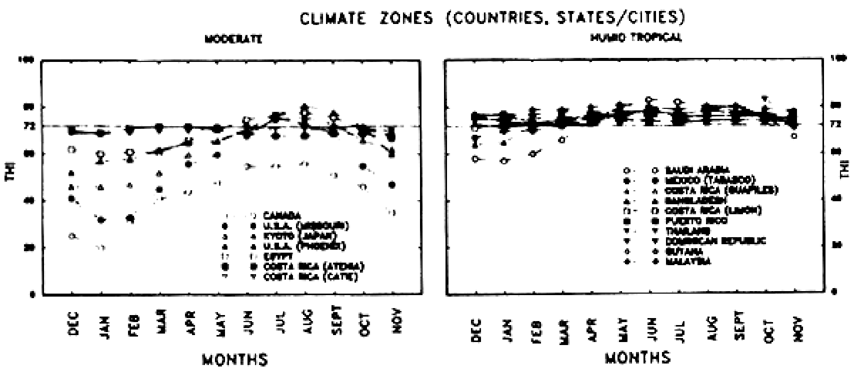


Figure 2.

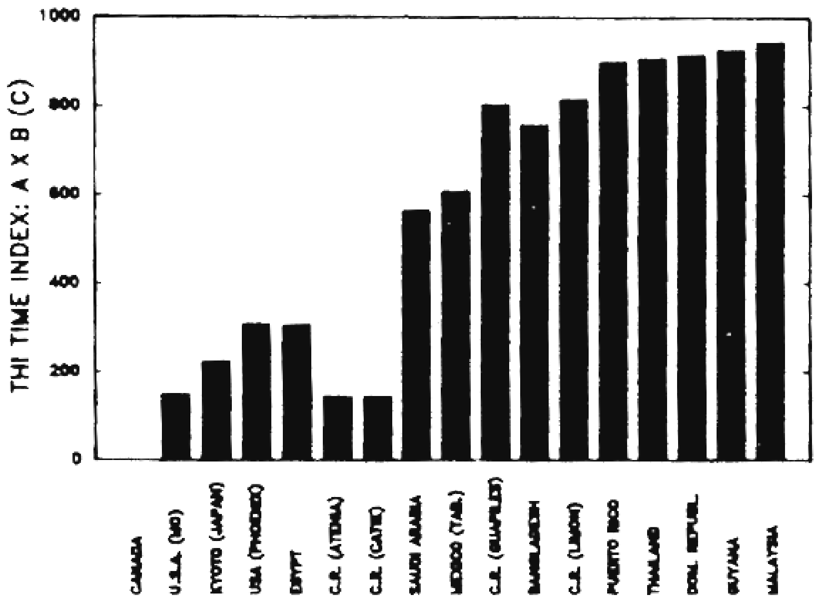


Figure 3.

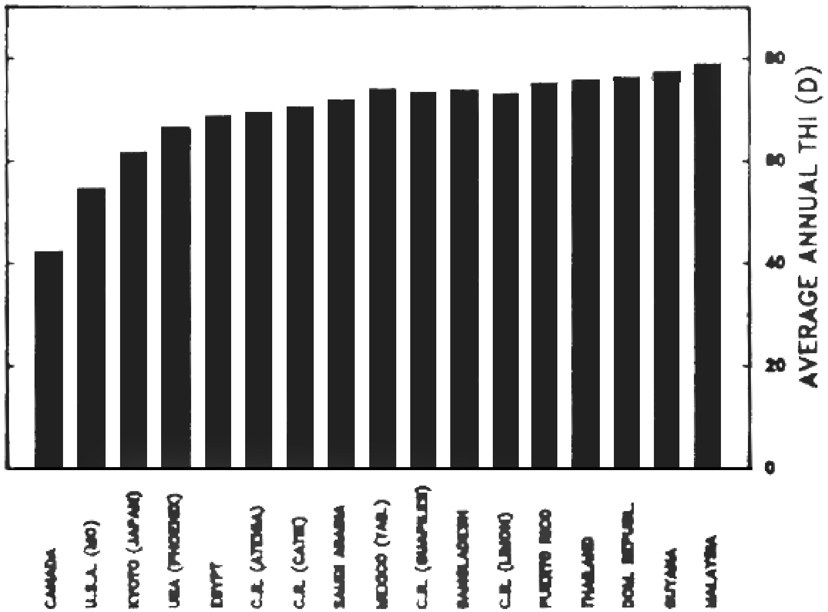


Table 1. Temperature Humidity Index - THI.

THI = T dry bulb + (0.36 T dew point) + 41.2�C

	Climate Zone	A. Ave. months above 72	B. No. months above 72	C. Time index: A � B	D. Average Annually
1	**Canada (Edmonton)**	0			42.2
2	**U.S.A. (Missouri)**	74.5	2	149	54.6
3	**Japan (Kyoto)**	74.7	3	224	61.6
4	**U.S.A. (Phoenix)**	77.0	4	308	66.6
5	**Egypt (So. Delta)**	76.5	4	306	68.8
6	**Costa Rica (Atenia) (low-land-dry)**	71.9	2	144	69.5

7	**Costa Rica (CATIE) (mid-altitude-humid)**	71.4	2	144	70.7
8	**Saudi Arabia (Hufuf)**	80.5	7	563	71.9
9	**Mexico (Cardenas, Tabasco)**	76.0	8	608	74.0
10	**Costa Rica (Guapiles) (low-humid)**	73.2	11	805	73.2
11	**Bangladesh (Dhaka)**	75.8	10	758	73.9
12	**Costa Rica (Limon) (low-humid)**	74.2	11	816	73.0
13	**Puerto Rico (San Juan)**	75.0	12	900	75.0
14	**Thailand (Bangkok)**	75.7	12	908	75.8
15	**Dominican Republic (Santiago)**	76.2	12	915	76.2
16	**South America (Guyana)**	77.2	12	926	77.3
17	**Malaysia (Kuala Lumpar)**	78.7	12	944	78.7

THE ENVIRONMENT, THERMAL BALANCE, FEED INTAKE AND MILK YIELD

A model of major factors of the ecosystem (not including other animals) which influence the ability of the cow or other livestock to lactate, grow and reproduce has been described by Johnson, 1987b. The meteorological factors include temperature and photoperiod and involve physiological mechanisms; the most important non-meteorological factors are quantity and quality of feedstuffs and disease factors. Environmental temperature (thermal factors) and possibly emotional factors signal the hypothalamus and central nervous system to alter feed intake, hormonal functions and heat production and/or loss with resultant declines in milk yield

and fertility.

In a thermal environment in which the animal's heat production exceeds heat loss, an increasing amount of heat is stored in the animal's body, resulting in increased body temperature. When the body temperature is significantly elevated, a myriad of homeothermic events are initiated. These events include increases in evaporative heat loss by respiration and skin. However, when high temperatures and radiation lessen the ability of the animal to radiate heat from the body, feed intake, metabolism, body weight and milk yields decrease to help alleviate the heat imbalance (Johnson, 1980a,b). Even though tissue substrates are mobilized, energy metabolism, growth and lactation declines.

To avoid this excessive acclimatization or adjustment to an adverse environment or to alleviate the stressor effects on less adaptable individuals, various management decisions and practices may be used to alleviate the severity of the climatic influences on the animal. These practices can help maintain the efficiency of production and prevent disintegration of the animal system.

The level of feed intake as indicated in Figure 4, is determined partially by the thermal balance of the animal which in turn alters milk yields and reproductive performance. Feed or hay intake declines in relation to THI which is illustrated clearly in Figure 4. The decline is about 0.23 kg/day for each unit increase in THI or increase in rectal temperature. The related decline in milk yield with increasing THIs is approximately 0.26 kg/day, milk decline/unit increase in THI (Johnson et al., 1961, 1962; Johnson, 1987b). A more recent study with 52 cows at each stage of lactation demonstrated the relative time changes in rectal temperature and milk yield and feed intake (Johnson et al., 1988). Milk yields of Jerseys and Holsteins from some of the countries previously discussed (Table 1) have been affected by the total environmental complex. These declines in milk yields for Holsteins or Jerseys in a temperate climate as

compared to the tropics are very great (approximately half of genetic potential). The somewhat lesser decline in Puerto Rico (half of genetic potential) may be due to data from the "hills" region, with improved genotypes and management practices (Table 2).

Figure 4. Regressions of milk yield, rectal temperature and feed intake on THI for many temperature-humidity conditions above thermoneutral (Jhonson et al., 1962).

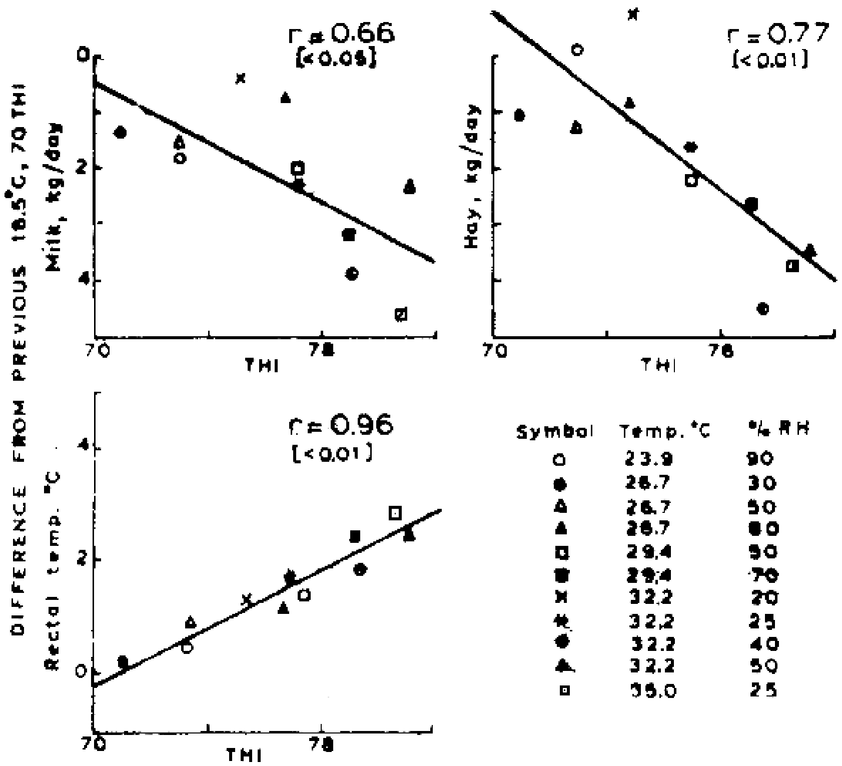


Figure 5. Seasonal heat effects in a temperate climate (Missouri) on conception rates.

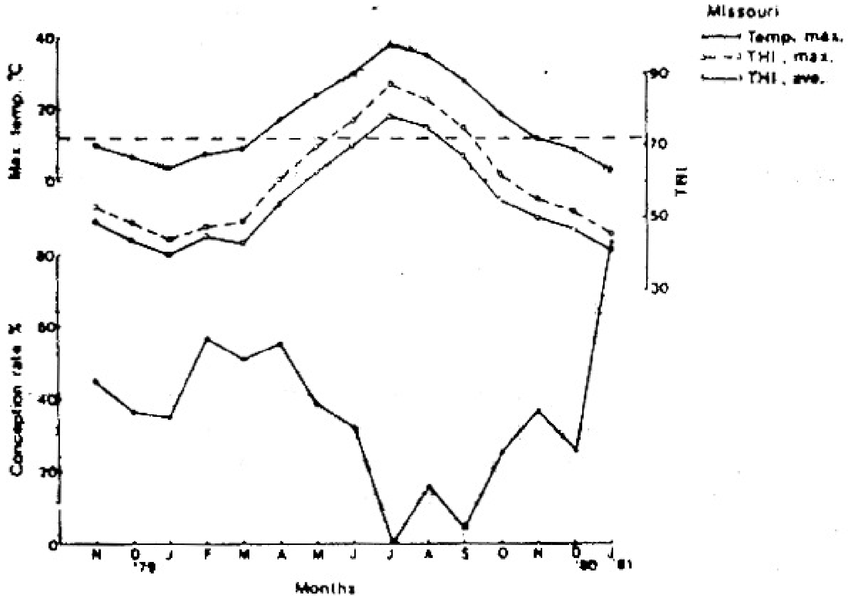


Table 2. Effect of tropical climate complexes on milk production of Holstein and Jersey cows.

Region	Annual Milk Production kg	Lactation Length days	Daily Milk Production kg	THI Animal (D)
Holstein				
United States[1]	7715	"305"	25	--
Arizona[1]	8331	"305"	28	66
Missouri[1]	6972	"305"	23	54
Puerto Rico[1]	4485	"305"	14.7	75
Mexico, Veracruz[2]	3534	"325"	10	73
Mexico,	2745	"305"	9	74
Tabasco[2]	----	----	9	69

Egypt	----	----	[illegible]	[illegible]
Guyana	----	----	6	77
Jersey				
Missouri	----	----	16	54
Mexico, Veracruz[2]	2537	"318"	7.9	72
Costa Rica, CATIE[3]	2218	"300"	7.7	71

[1] Wiggins, G.R., C.A. Ernst, U.S.D.A. Summary, 1987, Herd Averages,Beltsville, Maryland. Official National Cooperative Dairy HerdImprovement Program (NCDHIP), 1987.

[2]Roman-Ponce, H. 1987. Lactation of Dairy Cattle in Humid TropicalEnvironments. Chapter 6, pp. 81–90. From: Bioclimatology and theAdaptation of Livestock. H.D. Johnson, Editor. Elsevier Publishers,Amsterdam.

[3] Costa Rica, CATIE, 1986. Rolling Herd Average for Jersey.

MILK YIELDS AND REPRODUCTIVE PERFORMANCE AS AFFECTED BY ENVIRONMENTAL HEAT AND THI

The effects of THI on milk yields of Holstein dairy cattle have previously been summarized by Johnson et al. (1961, 1962) and Johnson (1987b). The influence of environmental heat and THI is especially critical to conception rates of temperate zone lactating cattle during summer heat (Figure 5; Rabie, 1983) and in the subtropics (Ingraham et al., 1976). Most evidence suggests that reproductive failures associated with hyperthermia in cattle are due to embryonic death

(Thatcher and Roman-Ponce, 1980; Putney et al., 1988) rather than insufficient LH, high prolactin or progesterone, which are responsible for ovulation and fertilization actions. Embryonic death may be due to thermal or uterine environmental changes (including hormonal or immunological changes; Spencer, 1988).

ALLEVIATION OR PARTIAL ALLEVIATION OF PRODUCTION LIMITATIONS

Nutritional

Decreased feed intake and a resultant decline in metabolizable energy (ME) intake is a major problem for the exotic (temperate) breeds of cattle imported into the tropics.

Nutritional Modification

The composition of the diet is believed to be important in alleviating heat stress. There are, however, no reliable scientific guidelines for feeding cows in hot climates. Milk yields did not change significantly in earlier studies where animals were forced to eat diets containing various ratios of forage/concentrate or isocaloric diets in which the ratio of fibre was varied (El-Khohja, 1979) or fat was added (Moody et al., 1971). We do know that cattle under heat stress will reach a hyperthermic state and will refuse forage but continue to eat concentrate.

Minerals

Since cows reduce their voluntary feed intake during hot temperate season weather and in the tropics (Collier et al., 1982), their mineral intake may also be less than optimal in hot weather, adding an additional limiting factor in hot humid environments. Kamal and Johnson (1978) also found negative mineral balances of cattle in which ration and total (urine and faeces) excretion were analyzed for Na, K, Ca, Mg, Zn, Cu, Fe, Co, Mo, and P.

Hormonal

Numerous hormones that are depressed in hot or tropical climates may warrant consideration as a means to prevent or restore milk yields of dairy cattle. Most promising is the bovine somatotropin (BST) which may soon be available commercially as a recombinant hormone. Prolonged heat stress was shown by our laboratory to lower plasma levels of growth hormone. Thus, assuming over-compensation may have occurred, the supplementation of growth hormone would increase milk yields and efficiency of energy conversion in hot climates. Recently Johnson et al. (1988), using the recombinant BST, increased milk yields under summer farm conditions by 18% and, in a subsequent laboratory simulated thermoneutral environment, by 25% and summer heat conditions by 26% over controls (Figure 6). The increase in milk, feed intake and metabolism did not increase body temperature more than controls due possibly to increased heat loss and/or efficiency of energy utilization (Johnson et al., 1987) (Figure 7).

Environmental (Shelter) Modification

Technology to avoid solar heat loads or increase heat losses from the animal to maintain heat balance is especially important for exotic temperate cows introduced into the humid tropics and during temperate zone summers. Shades have been shown by many scientists to minimize incoming radiation as much as 30% for the dairy cow and thus reduce heat loads (Roman-Ponce et al., 1977; Wiersma et al., 1984). Even in humid climates water sprays and high intensity fans can greatly improve milk yields (Igono et al., 1987, Johnson et al., 1987).

The effects of various temperature, humidity, wind combinations on milk yield and related heat balance measures were measured on lactating Holstein cows (Figure 8).

Genotype Modification: Production Adaptability Measures

Our goals are to provide the optimal micro-climate and micro-environment for the animal genotype, identify the genotype for adaptability as well as production potential and modify the genotype either by hormonal therapy (see above), or selective breeding. There are numerous examples of individual cows that are more heat tolerant and productive when subjected to heat stress (Johnson et al., 1962 Johnson. 1965; Johnson et al., 1967; Johnson, 1967; Johnson, 1987). Thus, selection can offer the potential to increase milk yield/cow in an existing microclimate, especially if selection includes production and adaptability indices (Horst, 1983; Johnson et al., 1988). These indices should improve stress resistance and avoid production compensation and excessive acclimatization.

A recent laboratory study on 51 cows at each stage of lactation demonstrated again a wide range of the ability of the individual cow with similar levels of milk yields (at thermoneutral) to produce when subjected to heat stress (Johnson et al., 1987) (Figure 9). These data clearly demonstrate that the milk yield and food intake of animals producing about 15–25 kg milk/day at thermoneutral (18°C) and were in the heat-tolerant portion of the population (Figure 9) declined less than the cows in the heat-sensitive portion of the distribution curve. This relationship of rectal temperature to performance (milk yield and feed intake) clearly describes the functional significance of thermal balance and energy-related functions.

Figure 6. Milk yields of control and BST-treated cows during summer farm and laboratory simulated TN and heat conditions.

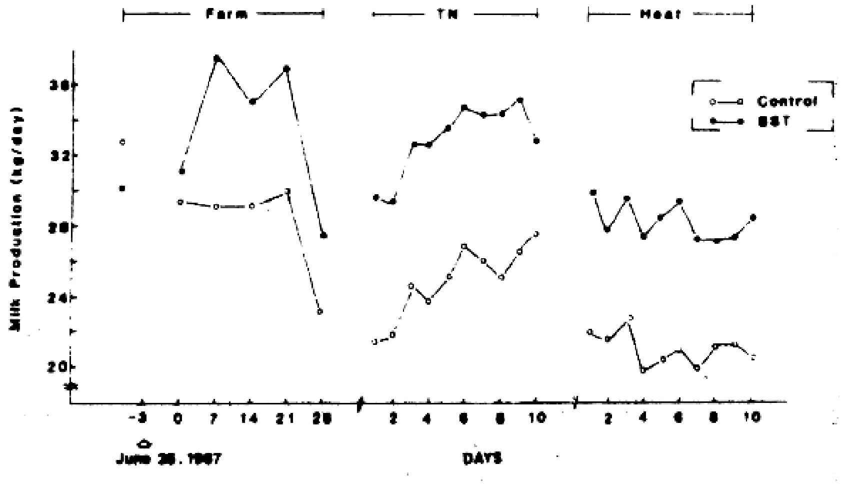


Figure 7. Milk production and rectal temperature of control and BST-treated cows.

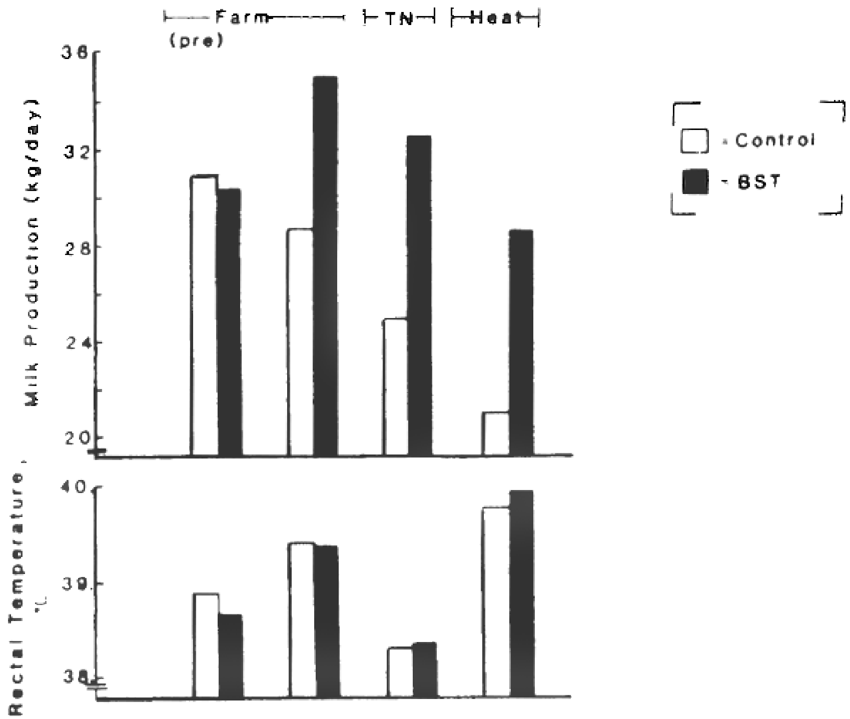


Figure 8. Changes in rectal temperature (°C) and % changes in milk yields under laboratory simulated and various combinations of temperature, humidity and wind. Control or base conditions wa 20°C, 40% RH and wind at 0.5 m/sec (MLS).

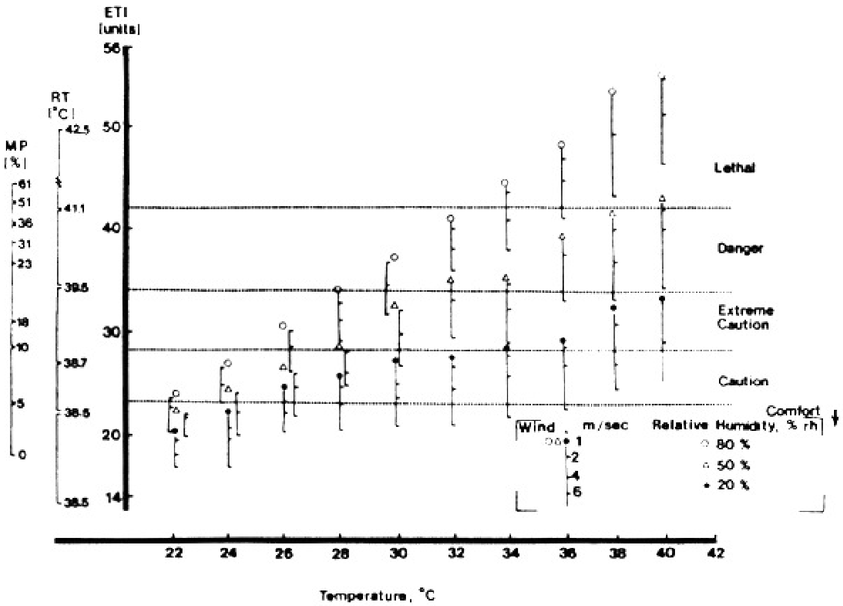
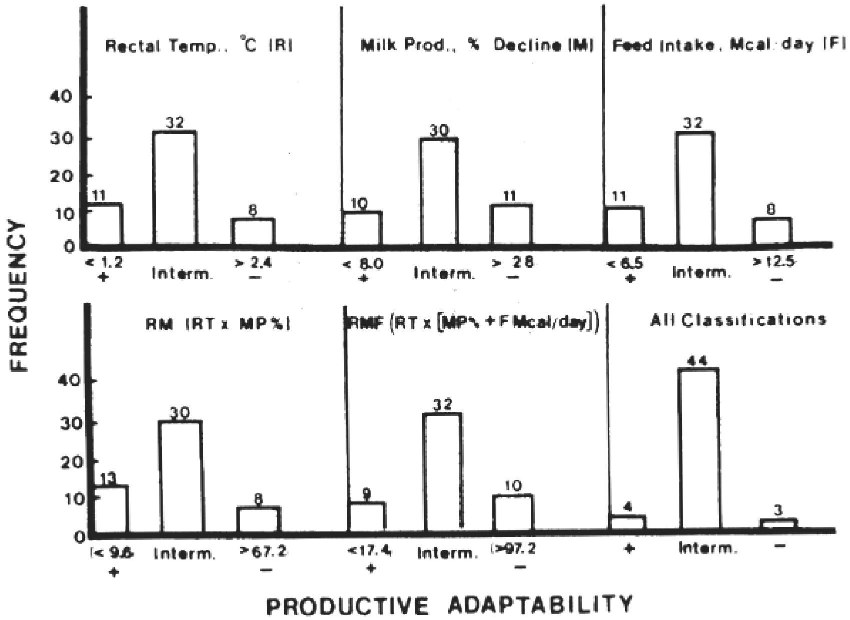


Figure 9. Frequency designations (-), (+) or (Intermediate) for productive adaptability indices (R = rectal temperature, °C; MP = milk production, % decline/day and F = feed intake, Mcal/day).



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PHYSIOLOGICAL CONSTRAINTS TO MILK PRODUCTION: FACTORS WHICH DETERMINE NUTRIENT PARTITIONING, LACTATION PERSISTENCY AND MOBILIZATION OF BODY RESERVES.

by

Y. Chilliard

Bovine milk yield is related to both intrinsic genetic and extrinsic nutritional and environmental factors. Milk composition is related more to genetic factors but is also linked, in part, to extrinsic ones.

On a short-term basis, the efficiency of nutrient use for milk production is primarily dependent on the milk production level. As milk yield increases, a lower proportion of total feed intake is used for maintenance (a non-productive requirement that is more or less constant) of the cow. A cow producing 12 kg/d of milk is using about 50% of available nutrients for milk synthesis, whereas the corresponding value is 66% when milk yield increases to 22 kg/d.

This point needs however to be reconsidered in the context of developing countries, especially in the hot and humid tropics. In these countries, several factors limit the use of high-yielding dairy cows:

- **highly digestible forages (and fertilizers used to produce them) are not available;**
- **cereal and other feeds of high nutritive value are not available in excess of what is needed for human or monogastric animal consumption, or are not available at an economic price;**
- **underfed specialised dairy cows decrease their milk production, but not enough to avoid excessive body weight loss, health and reproduction problems and even mortality;**
- **specialised high-yielding dairy breeds are not well adapted to climatic stress, to poor management and to endemic diseases and parasitism;**

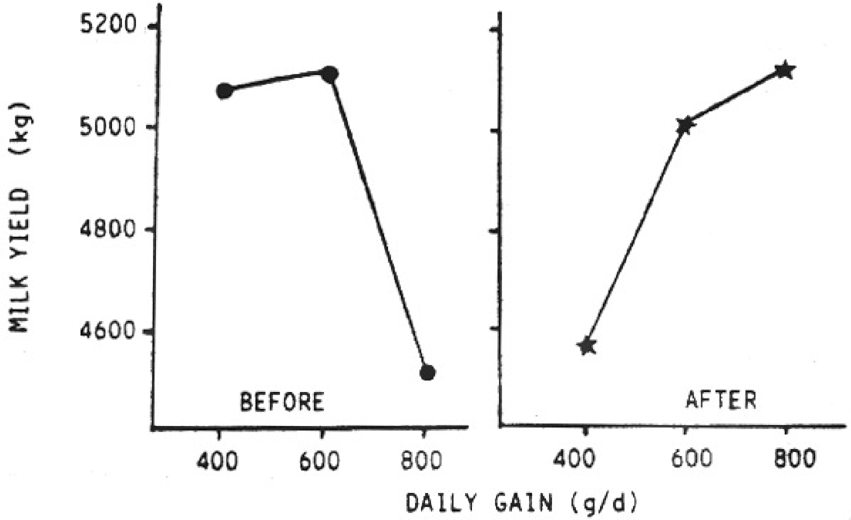
- **zebu or crossbred dual-purpose cattle and buffaloes are well adapted to tropical conditions, produce in some cases 1000 – 3000 litres of high-fat milk per lactation and can be used as draught animals (see Preston and Leng, 1987 and Roman-Ponce, 1987, for complete analysis).**

The present paper focuses on current knowledge of the physiological aspects of nutrient partitioning in lactating cows. Most data were obtained in high producing dairy cows from temperate countries. Therefore they do not apply directly to most milking cattle that are used in the tropics.

BODY GROWTH AND MAMMOGENESIS IN HEIFERS

Underfeeding of female dairy calves between birth and the first calving will decrease body growth, body reserves and will increase the rate of culling of the cows later (see also paper by J. Ugarte). Underfeeding during the first 4 months is more dangerous because there is little possibility of compensatory growth (see Johnson, 1988, and Troccon and Petit, 1989, for reviews). On the other hand, both underfeeding and overfeeding of heifers between birth and puberty can be detrimental to the milk production of the future cow (Figure 1).

Figure 1. Milk yield in 250 days of first lactation in relation to average daily gain before puberty (from 90 to 325 kg .) and after puberty (from 325 kg to first calving *). (Foldager and Sejrsen, quoted by Johnson, 1988)



The negative effect of overfeeding has been related to an excessive development of mammary adipose tissue at the expense of parenchymal tissue growth, which is allometric during this period. Overfeeding is also known to decrease age at puberty, and thereby the length of the allometric phase of mammary development. These results have also been related to a decrease in somatotropin (BST or growth hormone) secretion during overfeeding and there are data showing that injections of BST can increase the growth of mammary parenchyma in heifers before puberty. There are, however, no data showing that BST treatment of heifers will increase the future milk yield of the cow.

From puberty to first calving, an increase in feeding level is generally favourable to subsequent milk yield as well as to the overall growth and deposition of body reserves in heifers. After calving, primiparous cows are simultaneously growing and producing milk. This could explain why body lipid deposition after lactation peak is lower in primiparous than in multiparous cows (Table 1).

Table 1. Body fat (kg) in Holstein and Friesian dairy cows[1]

	Peripartum	Lactation peak	Mid lactation	Late lactation Dry period
Slaughter data[2]				
Robelin and Chilliard, 1983	122	41	-	35–122
Butler-Hogg et al., 1985	72	40	34–72	144
Dilution space data[3]				
Chilliard et al., 1984	81–90	51–68	90–96	-
Martin and Ehle, 1986	89–123	73	95	-
Vérité and Chilliard m	104	72	-	104
(unpublished) p	113	89	-	86

[1]See Chilliard (1987) for references.

[2]Dissectible adipose tissues

[3]Lipids estimated in vivo from body weight and deuterium waterdilution space
m = multiparous cows
p = primiparous cows

PHYSIOLOGICAL ASPECTS OF MAMMARY SECRETION

Mammary secretion is a function of the number of milk secreting cells and the synthetic activity of each cell.

The last phase of mammogenesis (lobulo-alveolar growth) essentially takes place during the second half of pregnancy. It is genetically determined and controlled by oestrogens, progesterone, prolactin, BST and other hormones that are also implicated in the differentiation of the mammary cells into cells that are able to make milk (lactogenesis stage I). The onset of

copious milk secretion (lactogenesis stage II) at parturition is due to elevated prolactin and adrenal steroids, simultaneous to progesterone withdrawal (Forsyth, 1983).

After calving, the metabolic activity of secretory cells is dependent on: (1) neuro-endocrine stimuli which are partly linked to suckling or milking. BST seems to be particularly important for the maintenance of lactation (galactopoiesis) in ruminants; (2) availability in arterial blood of nutrients that are used for milk synthesis (in most cases blood flow variations are consequences of tissue metabolic activities, but cardiac output could also be increased by prolactin and BST in non-lactating animals); (3) regular and complete evacuation of alveolar milk, to decrease intra-mammary pressure and to remove inhibitors that are secreted into the milk (feedback inhibition) (Mepham, 1983).

The decrease in milk yield after lactation peak (that determines milk persistency) results primarily from a decrease in the number of secreting cells. There is little knowledge on the possibility of manipulating the number of secretory cells during lactation. During extended lactation in the mouse, a stronger milking stimulus caused by new younger pups was able to increase the longevity of secretory cells, thus maintaining the number of cells at peak values and milk yield at two-thirds of peak values (suggesting that better milk persistency was due to cell number maintenance, whereas their metabolic activity decreased) (Knight et al., 1988).

Milk yield of dairy cows is clearly greater (25–40 %) when they are suckling their calves twice daily than when machine-milked twice daily. This could be due to a decrease of residual milk and/or to a better response of galactopoietic hormones to suckling (see Perez et al., 1985). Interestingly, when dairy cows suckle only during the first two months of lactation, they maintain an increased milk yield (above controls) after weaning, suggesting that the number of secreting cells was increased or that there was a carry-over effect on stimulating mechanisms (Everitt and Phillips, 1971). This can be relevant to simultaneous milking and suckling in dual-

purpose herds.

Hemi-mastectomy during lactation is followed by compensatory yield that is partly due to an increase in cell numbers in the remaining gland. During thrice-daily milking in goats, milk secretion was increased in the short-term (hours or days) by removal of chemical feedback inhibitor and increased metabolic activity, and in the long-term (months) by increased cell number (resulting either from increased cell proliferation or from decreased cell death rate). The latter is however in contradiction with results in cows previously milked thrice-daily over 20 weeks, in which the increased yield was not maintained when they returned to twice-daily milking. The same observation can also be made after removal of long-term BST treatment (Knight et al., 1988).

During concurrent pregnancy and lactation, there is a sharp decrease in milk yield during late pregnancy (after about 5 months in the cow), due primarily to increased oestrogen secretion that inhibits milk synthesis (and to some extent to competition for nutrients by the foetus). There is however at the same time a large proliferation of new secretory cells that will produce more milk during the following lactation (Knight et al., 1988). This proliferative phase is probably stimulated by drying-off the animals before the next lactation (Mepham, 1983). Hormonal induction of lactation in goats (without pregnancy) leads to lower milk yield and higher persistency, without change in mammary cell metabolic activities (Chilliard et al., 1986), probably due to lower mammogenesis and better cell maintenance.

Milk persistency between lactation peak and late pregnancy is also related to sustaining the metabolic activity of secretory cells (see above). It will be clearly related to adequacy of feeding (see below) and management (milking or suckling in good conditions) which enables expression of mammary cell secretory potential.

Under favourable conditions, unbred cows produce each month 94% of their yield during the preceding month. During a 5-year lactation, the yield of the 5th year was about 50% of that during the first (Smith, 1959). The same annual yield could be performed either with higher peak yield and lower persistency, or the other way round. Low persistency could be inherited or due to underfeeding or exhaustion of body reserves (see below) or to other unknown mechanisms that compensate for the higher solicitation of the mammary gland at peak yield. Persistency is indeed generally lower in higher producing animals, even if they are well fed (see Broster and Thomas, 1981 and Faverdin et al., 1987).

BODY RESERVES AND LACTATION IN THE DAIRY COW

Body fat at calving comprises 80–120 kg in “normally” fed Holstein x Friesian adult cows. The major part (but not all) of body lipids are stored in adipose tissues and can be lost during prolonged underfeeding. In well fed cows, the body fat that was lost after calving can be deposited again during declining lactation (Table 1).

Body proteins amount to 80–90 kg in Holstein cows, but most of them are structural components of the body and cannot be mobilized without irreversible degradation of the cow's potential. In underfed lactating cows, body protein loss estimated after slaughter or by deuteriated water did not exceed about 15 kg (20% of body protein), half of which was from muscles (Chilliard and Robelin, 1983). Body protein deposition in dry cows during fattening is lower than body protein loss in lactating underfed cows (Chilliard et al., 1987). This could explain why the muscle/bone ratio decreases in old cows (Robelin, unpublished data). A great part of body water variations is linked to body protein variations. Liver glycogen reserves are very limited and used on a short-term (day-to-day) basis.

The extent and duration of body fat and protein mobilization after calving depends on milk

potential, feeding level and quality, and initial body condition.

Effect of milk potential:

When milk potential increases (above 20 kg/d at peak yield), cows eat more feed but not enough to meet the mammary needs for nutrients, even with high quality diets fed ad libitum. Consequently, body weight loss (including lipids, water and protein) increases. Energy deficit lasted about 4 and 8 weeks in cows with peak milk yield of 20 and 40 kg/d respectively (Faverdin et al., 1987). However, when comparing different breeds of cows with the same milk yield, it was suggested that body weight loss was lower in dairy breeds (Holstein, Normandy) because of their higher feed intake capacity (Journet, Colleau and Piton, unpublished data). In respiratory chamber experiments with cows receiving 95% of their theoretical ad libitum intake, body energy loss was linearly related to milk production levels between 20 and 45 kg/d (Vermorel, Rémond and Vërité quoted by Chilliard et al., 1983).

In well-fed, high-producing dairy cows (more than 30 kg/d at peak yield), body fat loss was 30–60 kg during the first two months of lactation and body protein loss was 1–8 kg. In low-producing (7 kg/d), well-fed Hereford x Friesian cows, there was no significant body reserve mobilization (review by Chilliard et al., 1987). High producing dairy cows are able to maintain their milk yield only if their calculated protein deficit is lower than 10 kg during the first two months of lactation. This is in keeping with body composition data on body protein losses during ad libitum or restricted feeding (see above).

Effect of feeding level:

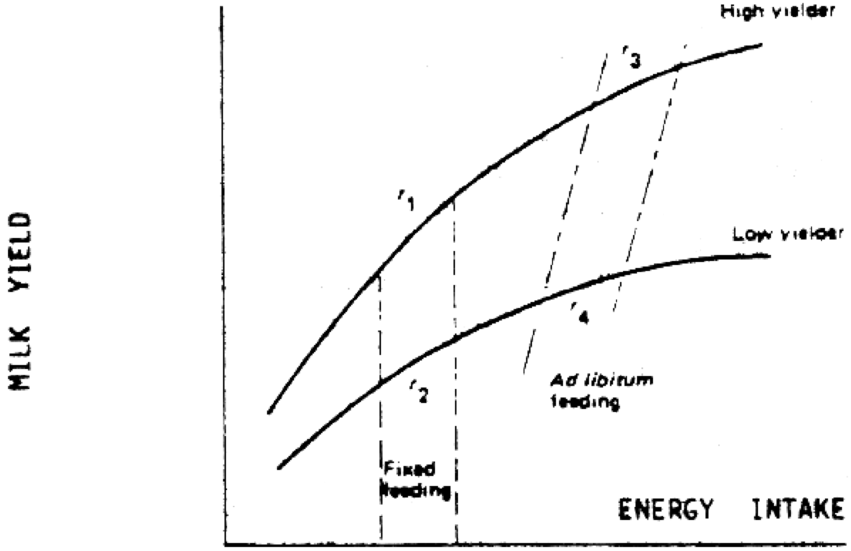
The immediate milk output response to metabolisable energy intake is curvilinear and follows the law of diminishing returns (Figure 2). When intake increases above mean theoretical

requirements for cow milk potential, the milk yield response is lower and supplemental energy is stored as body reserves. In underfed cows milk yield does not decrease in proportion to energy intake, due to the use of mobilized body reserves for milk synthesis. Curves in Figure 2 show that for fixed (low) amounts of feeds, high-yielding cows (that are more underfed) are more responsive to supplementary feeding than low-yielding ones. It is also probable that at a very low feeding level there is little difference in the actual milk yield of cows with different milk potentials, although further investigations concerning this point are needed.

In Holstein x Friesian cows with the same milk potential (28–29 kg/d) a feed restriction (25% below ad libitum intake) decreased peak milk yield (about-2.5 kg/d) and increased body fat (-12 kg) and protein (-5 kg) losses during the first two months. The same restriction in cows with higher potential (33 kg/d) further decreased yield (-1.0 kg/d) and increased fat (-10 kg) and protein (-7 kg) losses, when compared with restricted cows of lower potential (Chilliard et al., 1983).

Hereford x Friesian cows (11–13 kg/d at peak yield) in good body condition that were fed at maintenance level for 6 weeks after 70 days of lactation produced 7–8 kg of milk per day, and body fat loss was estimated to be 22–23 kg. Body fat could be deposited again, and milk yield maintained, if cows were refed at 2 x maintenance requirements for 6 weeks (Topps et al., quoted by Chilliard, 1987).

Figure 2. The response of low and high yielding cows to an additional input of energy.



When cows are moderately underfed during early lactation, they are able to produce again as much milk as control cows after peak yield, if feed allowances are sufficiently high (Broster and Thomas, 1981 ; Coulon et al., 1987; Table 2), suggesting that mammary potential was not irreversibly altered. More generally, milk persistency is affected by the level of underfeeding after peak yield.

Table 2. Effect of body condition at calving and feeding level on dairy cow performance and body reserves (Rémond, Chilliard and Larnicol, unpublished).

Body condition at calving:	**Fat**		**Lean**	
Dietary energy after calving[1]	**High**	**Low**	**High**	**Low**
Condition score at calving	3.6	3.5	1.4	1.6
Dry matter intake (kg/d)	19.8	15.1	18.8	14.7
Milk yield (kg/d)	30.4	28.9	28.9	26.0
Milk fat content (g/kg)	40.8	43.6	39.7	39.1

Milk protein content (g/kg)	32.2	30.4	32.4	31.0
Energy balance (Mcal/d)	-0.55	-8.71	+1.21	-
				4.49
Plasma free fatty acids (mM)	0.48	0.94	0.47	
				0.63
Adipose cell	-8	-21	-8	-15
diameter (μm)				
Body weight change (kg)[2]	-32	-59	+11	-11
Condition score change	-0.2	-0.6	+0.7	0.0
Milk yield (kg/d over weeks 19–44)[3]	15.6	16.6	16.2	14.7

Data are from 51 cows (11 to 14 per group) between weeks 1 to 8 of lactation.

[1] Protein (PDI, protein digestible in the intestine) concentration wasincreased in“low”energy diet in order to achieve similar PDIintakes in “high” and “low”groups.

[2]Corrected for differences in dry matter intake.

[3]45 cows only (8 to 14 per group)

<u>Effect of body condition at calving</u>:

Body condition scoring allows the assessment of subcutaneous fat variations by manual palpation of the tail head and the loin areas. With a 0–5 scale, in 49 Holstein x Friesian slaughtered cows an increase of one unit of condition score was equivalent to 35 kg of body

weight (r=0.69) and 28 kg of body lipids (r=0.85) (Rémond et al., 1988).

Body condition at calving is the result of body reserve mobilization and deposition cycles during the life of the cow, and more particularly during the previous lactation and dry periods. Increasing the level of feeding before calving generally increases subsequent milk yield (Broster and Thomas, 1981). This could be due to better mammogenesis and lactogenesis during the last weeks of pregnancy and the first days of lactation, to better digestive adaptation, as well as to better body condition (availability of body reserves) of the cow.

In well fed cows, body condition at calving has little effect on milk production, if the condition score is above 2. Fat cows generally have lower voluntary feed intake but produce the same amount of milk, due to body lipid (and probably protein) mobilization (review by Garnsworthy, 1988). These cows are however more susceptible to metabolic disorders (see following sections) and reproductive problems.

Differences between fat and lean cows are more pronounced during underfeeding. Underfed fat cows maintain their milk and fat yields due to a very high body lipid mobilization (Table 2). The decrease in milk protein yield and content is probably related in part to the low ability of body proteins to be mobilized. On the other hand, underfed lean cows still mobilize body reserves but not sufficiently to maintain their yield of milk, fat and proteins. In our trial they presented no higher incidence of health problems. When fed ad libitum from the 9th week, they reproduced normally and produced as much milk as fat cows from the "high"group during the second part of the lactation (Table 2). The excellent performances of lean cows that were well fed with high concentrate diet should also be underlined.

Body fat mobilization is also related to protein feeding. An increased supply of limiting amino-acids to the mammary gland can indeed increase milk yield and therefore the energy

requirement of the cows. This can lead either to increased feed intake (with highly digestible forages) or to increased body fat mobilization that will supply fatty acids for fat synthesis and oxidative energy in the mammary gland (Journet and Rémond, 1981). These hypotheses are confirmed by the fact that milk response to an increased protein supply was higher in fat than in lean cows (Garnsworthy, 1988). Peak yield increase could be, however, followed by decreased persistency (Broster and Thomas, 1981).

A knowledge of body stores is very important for understanding the long-term effects of underfeeding during several lactations (see Broster et al.,1984).In wiktorsson's trials, underfeeding during the first year did not affect peak yield but increased body weight loss and decreased persistency. On the contrary, continued underfeeding during the second year decreased peak and total yield, without further body weight loss (due to body reserve exhaustion, cf. Table 2). When cows were refed during the third year, nutrients were directed primarily to body gain and milk yield was not fully returned to control level.

REGULATION OF NUTRIENT PARTITIONING

Both exogenous and endogenous nutrients are used by the mammary gland. They are more available during lactation because of increased intake and digestion, as well as increased endogenous nutrient mobilization, or decreased competition, by other tissues and organs. The liver plays a key role in glucose production. Adipose tissue (muscles) can release or take up fatty (amino) acids, glucose and acetate. Mineral metabolism in the bones and gut is also involved.

During lactation, mammary metabolism is stimulated by galactopoietic hormones, among them somatotropin (BST) plays a central role. BST is also involved in the coordination of extra-mammary metabolism in order to ensure the priority of the mammary gland for nutrients

(teleophoresis, see Bauman and Currie, 1980). Knowledge on the mechanisms of BST action has increased very rapidly thanks to the treatment of cows with recombinant BST. Such a treatment rapidly increases milk yield but the feed intake response is delayed for 6-8 weeks. During this period body reserves are mobilized, but can be deposited again after several months of BST treatment in adequately fed cows (review by Chilliard, 1988).

The primary effect of BST is to stimulate the mammary gland, probably via stimulation of somatomedin production. BST also decreases glucose and amino acid oxidation, at the expense of adipose tissue long-chain fatty acids, and stimulates liver gluconeogensis. Part of these adaptations is due to BST counteracting insulin effects in various tissues. Lowered somatomedin secretion is partly responsible for "BST resistance" in underfed animals (Gluckman et al. 1987).

Insulin secretion and tissue responses to insulin decrease in early lactating animals whereas glucagon secretion is maintained or increased. This favours liver glucose production and adipose tissue mobilization (that is also favoured by higher beta-adrenergic sensitivity) and decreases glucose and amino-acid utilization in adipose tissues and muscles, but not in the mammary gland (see Chilliard, 1987). Thyroid hormones are also lowered during early lactation, possibly decreasing basal energy expenditure and protein turn-over (Aceves et al., 1985). The respective effects of teleophoretic hormones such as BST, and of the mammary drain of nutrients in metabolic and endocrine adaptations to lactation are not completely understood.

High-producing dairy cows have been selected for their ability to give a high metabolic priority to the mammary gland. If teleophoretic mechanisms overdo homeostatic regulation, several metabolic disorders can occur (milk fever, ketosis, steatosis, infertility, etc.), even in cows receiving high quality diets in temperate countries. This can partly explain why specialised dairy breeds are more subject to health problems under tropical conditions in developing

countries, contrary to local or crossbred cattle whose milk yield decreases more rapidly when they are underfed (Preston and Leng, 1987). Low milk potential could be considered as one facet of genetic and phenotypic adaptation to unfavourable conditions. Adaptation to heat stress is accompanied by changes in numerous lactogenic, galactopoietic or homeostatic hormones (Aceves et al., 1985; Johnson, 1987 and present meeting).

Efficiency of nutrient use for milk yield depends on the balance between glucogenic, lipogenic and aminogenic nutrients that are absorbed from the digestive tract and on absolute needs of the mammary gland for each particular nutrient (see Preston and Leng, 1987 and present meeting). It depends also on the effects of the absorbed nutrients on the endocrine state, particularly the insulin/BST ratio, and on the physiological needs of the cow to recover its "normal" body condition (see Chilliard, 1987). The efficiency of digestible energy utilization is decreased by heat stress, resulting in increased nutrient requirement at the absorptive level under tropical conditions (Roman-Ponce, 1987). As ambient temperature increases above 21°C, the cow lowers heat production by decreasing feed intake and milk yield, although some individuals are more resistant (Johnson, 1987).

Maintenance requirement represents a major portion of energy needs for cattle production and is consequently a major factor in overall energetic efficiency. Maintenance requirement is higher in high-producing dairy cattle breeds during weight maintenance periods without lactation. This is probably linked in part to the greater development of visceral organs with high protein turn-over (digestive tract, liver, heart, etc.) that are involved in handling larger amounts of feeds, nutrients and blood during lactation. This could also partly explain an increased maintenance requirement in the same animal during lactation, or according to previous higher feeding level (see Ferrell and Jenkins, 1985).

CONCLUSION

Knowledge of high-yielding dairy cow physiology and nutrition has rapidly increased during the last decades. Although not directly useful for milk production in tropical conditions, data on the effects of suckling, milking, underfeeding, body reserves, endocrine regulation and nutrient partitioning could probably be used as a basis for the planning and discussion of applied research, as well as for developing basic research, directly related to tropical conditions. In term of priorities, a particular attention has to be payed to feeding and management of late pregnant-early lactating cows, since they are more responsive at this physiological stage.

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INFLUENCE OF NUTRITION ON REPRODUCTIVE PERFORMANCE OF THE MILKING/GESTATING COW IN THE TROPICS

by

K-H. Lotthammer

Good milk production and numbers of calves per unit time are only obtained by achieving early conception in heifers and a short inter-calving interval in adult cows. Factors affecting fertility in dairy cows are numerous (Table 1).

Table 1. Possible factors affecting fertility in dairy cattle.

A. GENETICS		20 per cent
B. ENVIRONMENT		80 per cent
1. CLIMATE		- temperature, humidity
2. INFECTIONS		
3. PARASITES		
4. MANAGEMENT = FARMER		
a.	hygiene	

b.	HEAT DETECTION	
c.	suckling effect	
d.	FEEDING - NUTRITION (deficiency - excess) Rearing calves - HEIFERS - adult cows	
	Nutrients - contents of feed plants and concentrates	
	ENERGY - Protein minerals, trace elements vitamins	
	substances in food with negative influences on fertility (nitrate, goitrogens, oestrogenics-antioestrogenics, mycotoxins)	
e.	Food production	
	Fertilisation, quality of soil	
	Cultivation and preparing of feed plants and pasture	
C MALE FERTILITY		

It is estimated that about 80 per cent of the variance in fertility is due to environmental factors, of which more than 50 per cent is explained by nutrition, when severe infections and male fertility are excluded. Even predisposition to infectious diseases can be caused or increased by nutritional failures. Therefore balanced feeding is fundamental to milk production as well as health and fertility.

The present paper is mostly based on data which were obtained in dairy cows kept under temperate climate conditions, because of a lack of knowledge about relationships under tropical conditions. Except for some cases, the results should be seen as an indication of possible relationships.

In feeding dairy cows, three basic points must be considered in order to get good reproductive

performance:

1. **Balanced feeding is necessary throughout the year (lactation, gestation, dry period).**
2. **Reproduction can be affected by both an excess as well as a nutritional deficiency.**
3. **Interactions exist between the factors affecting fertility so that the combined effects are additive.**

The last point mainly applies to energy deficiency. Energy is an important nutrient for dairy cows both before and after calving and there is no substitute for energy in the diet of ruminants. A balance of energy and protein is required, even before calving and in the dry period (Table 2).

Table 2. Reproductive performance and frequency of metabolic diseases in dairy cows fed different levels of energy and protein in the dry period.

Feeding level:	Group 1	Group 2	signif.
	Maintenance + 16 kg FCM HIGH %	Maintenance + 2 kg FCM LOW %	
delayed uterine involution	53.6	17.2	**
puerperal endometritis	70.8	26.9	**
follicular cysts	44.8	18.7	*
conception rate with one or two inseminations	46.4	74.1	*
paresis pueperalis	26.2	6.3	*
subclinical acetonaemia	65.5	45.5	*

Lotthammer and Faries (1975)

As table 2 shows, all parameters of reproductive performances in Group 1 (overfed during the dry period) pointed to lower fertility compared to Group 2 with restrictive feeding (for maintenance and 2 kg milk). Furthermore the incidences of sub-clinical ketosis and parturient paresis were higher. Milk production after calving however was not increased (difference 0.5 kg/day), but the milk fat content was significantly elevated by 0.9% in the overfed group due to lipolysis. This effect, moreover, results in fatty liver. The metabolic stress is caused by a decreased intake after calving. Similar results were also obtained by Boisclair et al. (1988) and Flipot et al. (1988). There is a consensus among the authors that overfeeding should be avoided in the last stages of lactation to prevent fattening. About two weeks before the expected calving date, the cow's rumen should be prepared by a gradual increase in concentrates (0.5 kg per day more).

On the other hand, an energy deficiency before calving (below maintenance) should be avoided as well because this leads already at this stage to metabolic stress with subclinical ketosis and liver damage, followed by a higher incidence of retained placenta, endometritis and low conception rates in the following lactation.

The negative effect of an insufficient energy provision before calving will be enhanced by an energy deficiency after the following parturition. Probably due to the liver damage which occurs in this case, there is also an impact on fertility (Lotthammer, 1975; Reid et al., 1979). One also finds more severe infections of the udder, mainly from E.Coli. Furthermore we found that, in herds with a high incidence of liver damage, the response to vaccination against IBR/IPV (BHV-1) was significantly depressed. These results suggest an immunosuppression due to liver damage.

The importance of energy after parturition is well known. Already in the first two to three weeks of lactation, energy from any source is important for the onset of ovarian activity (Butler et al.,

1981; Terqui et al., 1982; Villa-Godoy et al., 1988) and, related to this, for uterine involution. Energy deficiency leads to acyclia, silent heat, delayed ovulations and follicular cysts. Significant correlations exist between fertility and weight loss or body condition, as indicators of negative energy balance in the first weeks after calving (Oxenreider and Wagner, 1971; Godfrey et al., 1982; Rutter and Randel, 1984). Weigelt et al. (1988) also report embryonic mortality in cows with energy deficiency. The effects of energy intake on reproduction follow the pathway summarized in Figure 1. That even the result of therapeutic treatments of reproductive disturbances such as endometritis depends on the nutritional status is demonstrated in Table 3.

Under tropical conditions in the dry period, energy provision is insufficient and related to fertility problems. This is suggested by the field investigations of Betancourt et al. (1985) carried out in Columbia with the dual purpose zebu (Figure 2). More exactly, we could demonstrate the correlations between energy and reproduction in relation to the seasonal conditions in Pakistan in milk buffaloes (Figure 3).

Figure 1. Effects of energy imbalance and acidosis ante- and post-partum on health and reproductive performance in dairy cows (Lotthammer 1987).

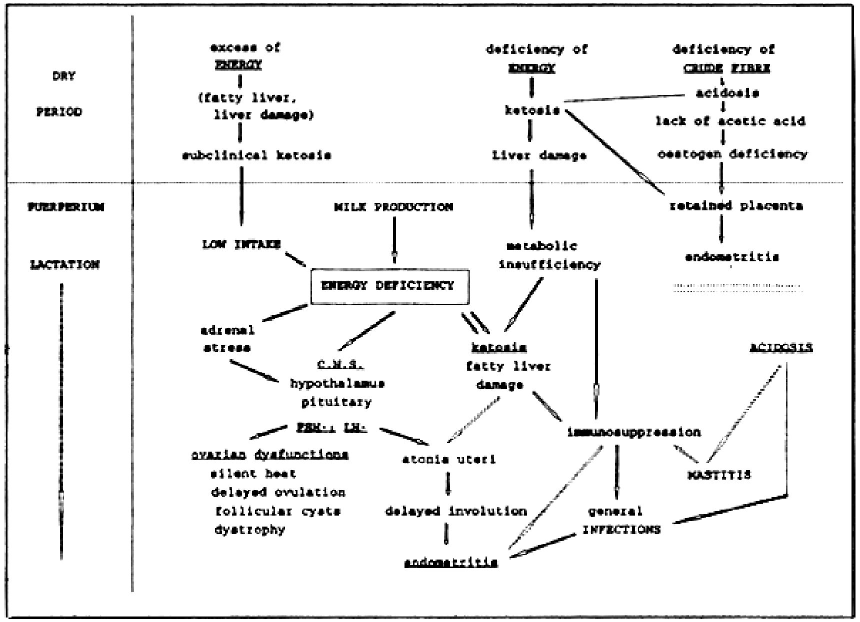


Figure 2. Monthly amount of rainfall in Cordoba (Colombia) and percentages of static ovaries in dual purpose Zebus in the dry (Jan to May) and rainy season (June to Dec) (Betancourt et al., 1985).

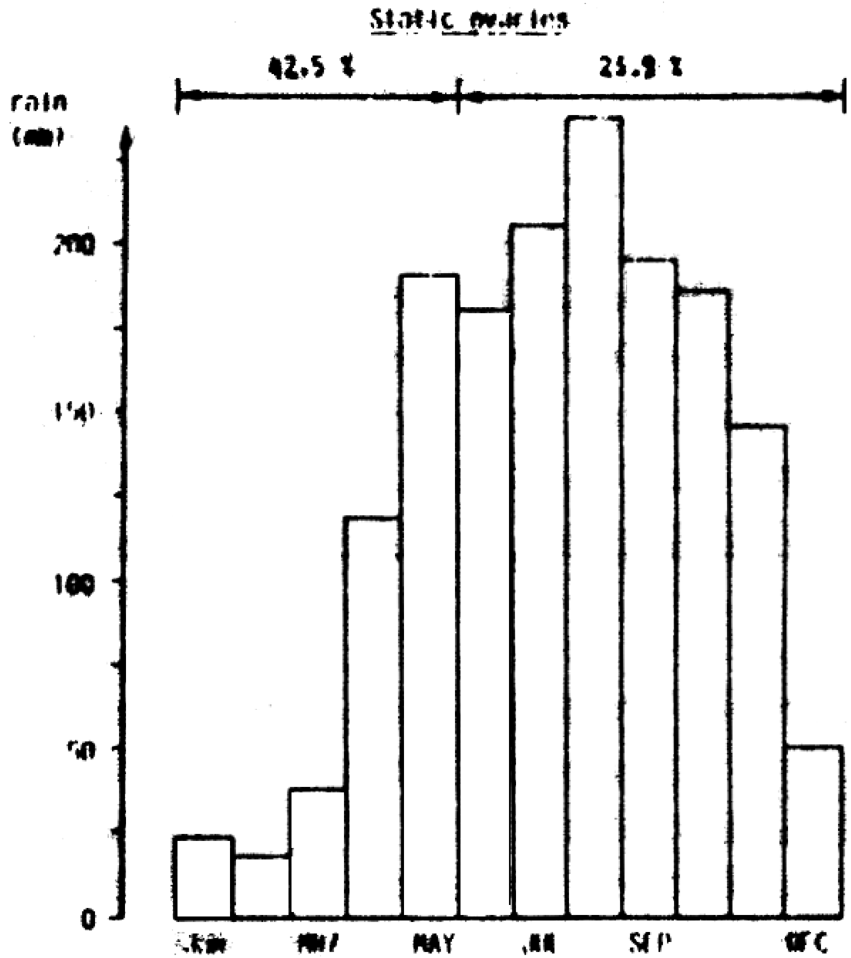


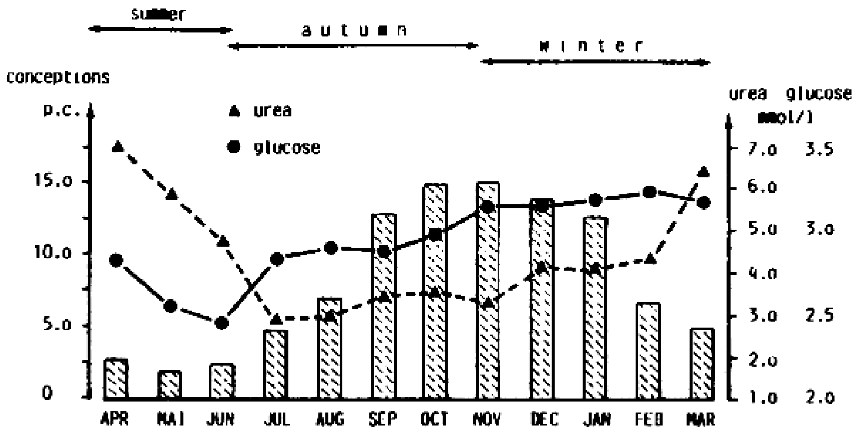
Table 3. Results in pregnancy, number of treatments and inseminations per pregnancy after treatment of puerperal and postpuerperal endometritis and losses in cows with different nutritional status and health.

Parameter	**nutritional status/health**		**energy deficiency liver damage**
	normal	**energy deficiency excess of protein**	
% of pregnancies	94.4	81.0	54.5
treatments per cow	1.22	1.46	1.66

inseminations/pregnancy	1.39	2.19	2.59
interval treatment - conception (days)	48.50	66.90	68.30
costs of treatment/conception ($)	17.-	24.-	40.-
differences to "normal" group by costs of treatment and losses per cow ($)		+ 78.-	+ 100.-

(Escherich and Lotthamer, 1987)

Figure 3. Monthly distribution of conceptions and concentrations of glucose and urea in blood serum of milk buffaloes in the course of the year (Bode, 1989).

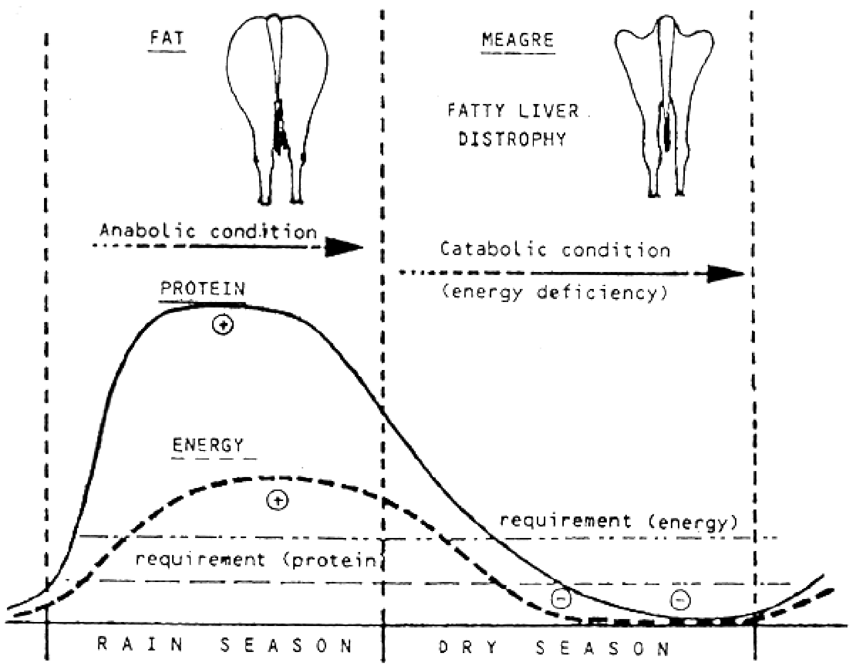


As Figure 3 demonstrates, the glucose levels in the (dry) summer are at a minimum and they increase with the beginning of rainfall in the autumn. At the same time, the percentage of conceptions increases too. This suggests that, with better feeding conditions following rainfall, the energy supply is also improved which results in a higher conception rate. The high urea levels in the dry period indicate imbalanced energy/protein supply too, due to an energy deficiency.

Figure 4 illustrates the problem of providing energy and protein in regions with a dry and rainy season. The nutritional conditions are changing between high intake and deficiency with consequences for metabolism. This mainly influences reproduction in the dry season. To get better results, efforts should be made to balance these conditions. That means transferring part of the surplus from the rainy season to the dry season by the following activities:

1. **Ensilage of well grown feed plants (king grass, corn, etc.)**
2. **Introduction of new feed plants (corn or other) (Lotthammer, 1982)**
3. **Irrigation of grassland to shorten the dry period and to extend the period of vegetation**
4. **Good grassland management.**

Figure 4. Schematic situation of energy and protein supply in regions with a rainy and dry season.



The importance of protein sometimes seems to be overestimated, if it is appreciated that ruminants are producing about 70% of their "own protein" by means of microbes in rumen. These need mainly energy in the form of carbohydrate. This means that, with normal rumen conditions for the microbes, ruminants are already supplied with protein and energy via gluconeogenesis. This could be demonstrated by Kaufmann (1976) and is indicated by the positive correlation between energy intake and protein content in milk.

We found a curvilinear correlation between conception rate and protein supply. Protein deficiency as well as an excessive protein supply causes acyclia and low conception rates.

The negative effect of a relatively excessive intake of protein is enhanced by energy deficiency at the same time. Under these conditions, a large amount of ammonia is flowing through the liver and causes liver damage. In these cases we find static ovaries, silent heat, anaphrodisia, purulent endometritis and embryonic mortality. This can be caused by alterations of uterine secretions (Jordan et al., 1981, Ferguson and Chalupa, 1989). Uterine treatments with antibiotics or other preparations in these cases are not very successful until nutrition is balanced (see Table 4) and therefore they are not economic.

Table 4. Incidence of diseases in health and fertility post-partum after grazing on pastures with different concentrations of nitrate in grass dry matter.

Disease	**NO_3^- concentration in dry matter (%)**		
	<0.30	**0.30–0.50**	**>0.50**
Paresis	0	6.1	17.2
Puerperal endometritis	25.0	36.4	44.8
Retained placenta	0	13.6	10.3
Abortions/stillbirths	7.1	6.1	3.4

Minerals

For many years, phosphorus deficiency was given as a main cause of infertility. Legel (1970) demonstrated in a definitive experiment that phosphorus deficiency decreased total intake which caused a lower energy supply and lower weight gain in heifers. A negative effect on reproduction was not found. In the case of stress, the negative effect of P deficiency is enhanced. The Ca:P ratio also seems to be important. The results of our experiments show that the frequency of non-infectious endometritis is increased when Ca:P ratios decrease. Furthermore a lower content of managanese is found in uterine tissue.

This also demonstrates the importance of calcium, which has functions for the uterine performance, especially after calving for involution of the uterus. The advice is to keep Ca: P ratio in total intake over 2:1 with marginal P supply which should be higher under stress conditions. Depending on soil quality and fertilizer use, a deficiency of sodium and a correlated excess of potassium can reduce fertility by irregular oestrus cycles, endometritis and follicular cysts (Lotthammer and Ahlswede, 1973). The Na:K ratio should be kept under 10:1. Sodium supplementation by salt is very cheap and should be given ad libitum.

Of the trace minerals, manganese and selenium may influence reproduction. Manganese supply is correlated with pH value of the soil because high pH values inhibit uptake from the soil. A deficiency of manganese produces anaphrodisia, endometritis and abortions (Anke et al. 1987). Daily supply per cow should be 1000 mg. Recently selenium deficiency has been discussed, in combination with vitamin E, producing retained placenta, endometritis and cystic varies (Harrison et al., 1986). The authors state that only a combined treatment with selenium and vitamin E improves fertility.

Vitamins

Of the vitamins, vitamin A is seen nearly exclusively as the factor affecting fertility. In several experiments with heifers and milking cows, we could demonstrate a negative effect of B-carotene deficiency on fertility, unrelated to vitamin A (Lotthammer, 1979). The failures are silent heat, delayed ovulations, follicular and luteal cysts, early embryonic mortality and diarrhoea in calves. These problems occurred in spite of sufficient vitamin A. The daily supply needed is 125 mg for dry cows and heifers and about 300 mg for milking cows. The carotene status is easily observed by the colour of the serum.

The effect of vitamin E deficiency cannot be separated from selenium deficiency (see above). Both must be considered to prevent fertility problems. The requirement will be supplied by green feed or silage.

Other factors

Under certain conditions, some substances in plants can affect health and fertility. As pointed out above (Table 4), fertility problems increased with higher concentrations of nitrate in grass. The content of nitrate in plants is positively correlated with dry conditions and fertilization with nitrogen. Energy deficiency enhances the negative effect. Also some plants (e.g. Cruciferae) have high concentrations of nitrate.

Other substances in plants are oestrogenic. These substances can be produced by plants themselves (Trifolium) or by fungi on plants and fungi cause problems in tropical areas. The oestrogenic substances influence fertility directly via the ovaries in a very severe way (Kallela, 1968; Lotthammer et al., 1970). Avoiding the growth of fungi is the best way to prevent disturbances.

Conclusion

More research is needed to increase our knowledge of the effects of nutritional factors affecting fertility and health. Furthermore, more work is needed to determine the contents of all nutrients in local feeds, in relation to season and soil conditions.

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THE ROLE AND MECHANISMS OF GENETIC IMPROVEMENT IN PRODUCTION SYSTEMS CONSTRAINED BY NUTRITIONAL AND ENVIRONMENTAL FACTORS

By

Ola Syrstad

INTRODUCTION

One of the many constraints on milk production in the tropics is the poor genetic potential of the indigenous animals. Tropical cattle are mostly of zebu (Bos indicus) type. These cattle are well adapted to the conditions prevailing in the tropics. Natural selection over hundreds of generations has provided them with a high degree of heat tolerance, some resistance to many tropical diseases and the ability to survive long periods of feed and water shortage. However, their dairy potential is poor; they have low milk yield, they are late maturing and usually do not let down milk unless stimulated by the sucking of the calf.

Genetic improvement alone might not result in drastic increases of milk production in the tropics, but it is a prerequisite for such increases. Genetically more productive animals are also the best incentive to improved feeding and management.

GENOTYPE AND ENVIRONMENT

The performance of an animal is the result of the joint action of its genotype and the non-genetic effects to which it is exposed. The non-genetic factors are often collectively termed the “environment”.

The genotype is often conceived as a frame which restricts the performance to a given level. Below this level, the performance is determined by the environment. This concept is visualized in Figure Ia. Two genotypes, A and B, are considered. The superiority of the better genotype, A, is expressed only if the environment is more favourable than that which is necessary to exploit fully the potential of the poorer genotype, B. When the environment is worse than this,

both genotypes would perform similarly and genetic improvement beyond the level of B would be of no use. According to this model both genotype and environment can act as bottlenecks which restrict performance. Although this might seem reasonable, the available evidence indicates that the concept is in general not providing an appropriate description of the interaction between genotype and environment.

The model illustrated in Figure 1b is much more likely to be correct in most cases. Here the superiority of the better genotype, A, is realized, regardless of the environmental conditions, but the difference between the two genotypes increases as the environment improves. This means that genotype A responds more to improved conditions than genotype B (indicated by the steeper slope of the line), but the genetic difference is expressed also under poor conditions. Most research on genotype - environment interaction in dairy cattle supports this model (review by Syrstad, 1976). In studies on field data, progenies of various bulls have been found to rank very similarly over a wide range of production levels. The same was true when progenies of the same bull in Mexico and U.S./Canada were considered (McDowell et al., 1975). A recent review of dairy cattle crossbreeding in the tropics (Syrstad, 1989) suggests that the relative merits of two genetic groups (1/2 vs. 3/4 exotic inheritance) is independent of production level.

Figure 1. Different models of genotype x environment interaction. For explanation, see text.

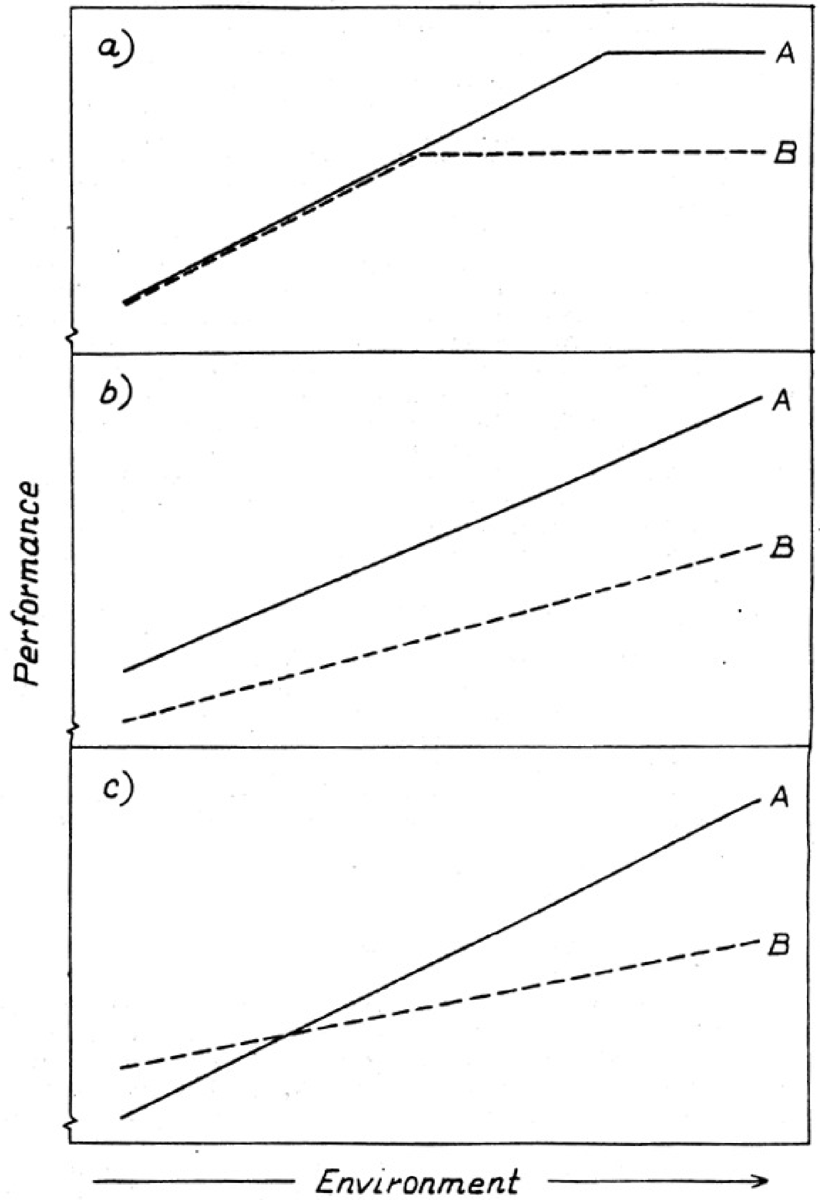

Figure 1c describes a situation in which the different responses of the two genotypes to environmental improvement results in reversed ranking. Genotype A is the better under good conditions, while B is superior when the environment falls below a given level. This might occur

in cases when the environment varies over a very wide range. An example from beef cattle is presented by Hearnshaw & Barlow (1982). Crosses of Hereford with Friesian, Simmental and Brahman (American Zebu) were compared under good, intermediate and poor pasture conditions. The Friesian and Simmental crosses were the best on good pasture, while Brahman crosses were superior on poor pasture. In dairy cattle, Buvanendran & Petersen (1980) found almost no relationship between the performance of daughters of the same bull in Denmark and Sri Lanka. However, the number of daughters in Sri Lanka was small, and the lack of association might be incidental.

Model (b) suggests that the best breeding strategy is to select breeding animals on their performance in a good environment, as this is when the genetic differences between animals is most clearly expressed. But this would be dangerous if model (c) should be correct. The safest, and usually the most efficient, approach is to base selection on the merits of the animals as expressed under environmental conditions similar to those which their progenies will be exposed to.

METHODS FOR GENETIC IMPROVEMENT

a) Selection within the local population

Cattle indigenous to the tropics have, except in very few cases, been subjected to only little artificial selection for increased milk production. In view of the impressive results achieved by selection in many temperate dairy breeds there should be good prospects for improving the dairy potential of tropical cattle by the same method.

Genetic improvement per generation from selection depends on the variability of the traits considered, their heritability (i.e. the proportion of total variation which can be ascribed to

genetic differences), and the intensity of selection. Variability, in terms of the coefficient of variation, is usually greater in tropical than in temperate cattle, but the variation in actual units is less. Studies of heritability based on sufficiently large amounts of data are few, but estimates reported fall within the same range as those from temperate countries. Intensity of selection is restricted by the reproductive rate, and is further reduced by early mortality, which often is high under tropical conditions.

Many dairy cattle breeding programmes claim a genetic improvement in milk yield of one to two percent per year. Of this improvement, 60 to 70 percent is derived from the selection of bulls on the basis of the performance of their daughters (progeny testing). This is achieved by a combination of accurate progeny testing (i.e. many daughters per bull) and intensive selection (many bulls tested per year). These conditions can be fulfilled only in large populations, comprising tens (if not hundreds) of thousands of females, artificial insemination, and widespread milk recording.

In most tropical countries such populations do not exist, and are not likely to be available in the foreseeable future. Instead a breeding programme might have to be established in a single herd or a few cooperating herds. In order to make progeny testing worthwhile, even strictly on genetic grounds, several hundred females would be needed. Still, the high costs involved might not make such a programme attractive. But if the herd serves as a nucleus herd, also providing bulls for breeding outside the herd, the benefit of genetic progress will in turn be transmitted to a much larger number of animals, and it might be justified to maximize genetic progress in spite of high costs. Thus a rather small breeding scheme can have tremendous impact if organized and operated properly.

b) <u>Introduction of improved tropical breeds</u>

Some breeds of tropical cattle, e.g. Sahiwal and Red Sindhi, have been selected for increased milk yield over a long time and have reached a much higher dairy potential than most cattle in the tropics. This is a genetic resource which should be exploited for upgrading of unimproved stock. After a few generations of back-crossing to bulls of the improved breed, the inheritance of the local cattle has been almost completely replaced by the improved inheritance. The risk of losing adaptability to local conditions by this method is small, a breed like Sahiwal has shown to adapt well to conditions in four different continents. An improvement which would require ten generations of intensive selection could be obtained in two or three generations of upgrading with an improved breed. Unfortunately the number of animals of improved tropical breeds is small, and breeding stock of high quality are not easily available.

c) Introduction of temperate breeds

Reports on the high milk yields in some temperate countries have spread the belief that the importation of European-type dairy breeds is the solution to the problem of low production levels in the tropics. In some cases introduction of temperate breeds has been successful but much more often the experience has been disappointing and sometimes almost disastrous. Diseases, high mortality rates and low fertility have been frequent problems among the imported animals and their progenies, and animals which have survived have failed to reach the expected production levels. Offspring born in the tropical country have often produced much less than their dams, which were imported as heifers. The lack of adaptation to tropical conditions has been obvious. On the basis of experience up to this time, purebred European-type dairy cattle can be recommended in the tropics only if climatic stress is moderate, health services are easily available and reasonably good feeding is practised.

d) Crossbreeding with European type cattle

Crossbreeding of tropical cattle with cattle of European-type breeds has occurred for more than one hundred years, and a large number of reports has been published. In most cases, females of local stock have been mated to bulls of the imported breed or by the use of imported semen.

In almost all cases, crossbreeding with a European breed led to a dramatic increase in milk yield in the first crossbred generation (F1), compared with the local stock. The crossbred females calved at a much younger age than native animals, produced two to three times more milk and had longer lactations, shorter dry periods and shorter calving intervals. Mortality and susceptibility to disease were only slightly higher than in native cattle.

These favourable results were, naturally, ascribed to the superiority of the exotic inheritance, and it was tempting to introduce more of it by backcrossing to exotic bulls. But the expected further improvement did often not occur and in many cases a decline in performance was observed. Problems of high mortality and reduced fertility increased as the level of exotic inheritance increased towards 100 per cent.

When it had been found that upgrading towards the European breed was not advisable under most conditions, the next step was to try to stabilize the level of exotic inheritance by mating F1 males and females together. But again the results were often disappointing. In almost all projects the performance of the second half-bred generation, F2, has been much below that of F1. Age at first calving and calving intervals have increased considerably and milk yield has dropped by up to 30 per cent.

A summary of results from 54 sets of data reported from cross-breeding experiments in various regions of the tropics is presented in Table 1. The good performance of the first crossbred generation (F1) and the deterioration in the next generation (F2) are clearly

demonstrated. The most obvious explanation is the presence of hybrid vigour (heterosis); this effect is maximized in the F1 but half of it is expected to disappear in the F2 and forward generations. In addition other genetic mechanisms might also be involved.

The great effect of hybrid vigour in crosses of zebu x European-type cattle might be expected because of the wide genetic distance between the two types (Cunningham and Syrstad, 1987). Furthermore it has been suggested that hybrid vigour is more important under stressful than under favourable environmental conditions (review by Barlow, 1981). The breeding strategy for dairy cattle in the tropics should therefore also aim at exploiting hybrid vigour. Exactly how this can be done under various conditions is still a question for discussion, and more research is needed.

Table 1. Performance of zebu cattle, European type cattle, and their crosses in the tropics. Summary of 54 sets of data. Source: Syrstad (1988).

Proportion European cattle	Age at first calving, months	Milk yield, kg	Calving interval, days
0 (i.e. zebu)	43.6	1052	459
1/8	40.1	1371	450
1/	37.5	1310	435
3/8	36.1	1553	435
1/2 (F1)	32.4	2039	429
5/8	33.8	1984	432
3/4	33,9	2091	450
7/8	34.4	2086	459
1 (i.e. European)	31.6	2162	460
1/2 (F2, from F1xF1)	33.7	1523	449

Table 2. Comparison of F1 and backcrosses (1/2 and 3/4 European inheritance) at low, intermediate and high production levels. Summary of 30 sets of data. Source: Syrstad (1989).

Production level	**Average milk yield, kg**	
	F1	**Backcrosses**
Low (<2000 kg)	**1487**	1605
Intermediate (2000–2405 kg)	**2175**	2218
High (>2405 kg)	**2798**	2698

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MATCHING LIVESTOCK SYSTEMS WITH AVAILABLE RESOURCES

by

T R Preston

DEVELOPMENT MODELS

The Third World

In the tropical regions of the Third World in general and specifically at the level of the small farm, livestock production is in crisis. This crisis is closely related with the production models

which were implanted in Third World countries during the post-war period and were intensified in the decades of the 60's and 70's. In order to introduce these new technologies, many Third World countries established credit mechanisms, agricultural research programmes, rural extension schemes, and training programmes aimed at increasing production by promoting an increase in the productivity of crops and animals.

The model that was advocated for the agronomic sector aimed to bring about a "green revolution", specifically in cereal grain production, that would solve the nutritional problems and hunger suffered by millions of people in the Third World. "Improved" production systems were promoted, based on high performance germ plasm, monocultural practices and the intensive use of capital, machinery, and costly imported inputs such as fertilizers, pesticides and herbicides.

In the livestock field, priority was given almost exclusively to the introduction of systems, the technical and economic bases of which were derived from experiences in the temperate, "industrialised" countries, where emphasis had been on low labour inputs, high use of capital, and intensive specialised production methods aimed at market expansion. For example:

- **Cattle production systems were based on the American and Australian models that employed extensive grazing on pastures established in regions previously in natural forest. The result has been an alarming increase in erosion and destruction of ecosystems and watersheds.**

- **Pig, poultry and milk production systems were based on "economy of scale", involving an ever increasing dependence on "imported" inputs (feed grains and protein meals, germ plasm, drugs, equipment and fossil-derived fuel), and an overall negative effect on employment opportunities, especially in rural areas.**

The result of these activities has been an increasing dependence on imported inputs, increased costs of production, reduced rural employment, contamination of the environment and destruction of ecosystems, deforestation and under-utilization of available resources.

The industrialised countries

The transfer of livestock technologies from industrialised to developing countries, has obviously been largely unsuccessful. Quite apart from the reasons for such failures, it is relevant to question the basic concepts governing the models currently employed in the industrialised countries. For, contrary to what is so often assumed, it may not be desirable - even if it were technically and economically feasible - to attempt to achieve in Third World countries the styles and standards of living currently "enjoyed" (??) in the industrialised countries. Leaving aside the social issues, an assessment of the present agricultural situation in most industrialised countries shows that:

- **agricultural products - especially those of animal origin - are expensive to produce and to buy,**
- **present production systems are wasteful and cause considerable ecological damage,**
- **the systems of production and the products that are produced are frequently associated with stress both for animals and humans, and**
- **the dependence on, and excessive use of, fossil fuel based inputs is causing an alarming increase in atmospheric carbon dioxide concentrations, which is the main contributer to the warming of the earth's atmosphere - the "greenhouse effect."**

It hardly seems sensible to encourage the developing countries to commit their scarce

economic resources to livestock production programmes which may eventually arrive at the same inappropriate endpoint.

Eco-development and self-reliance

The concept of eco-development has been proposed by Third World economists as an alternative to the classical development models derived from the industrialised countries, which have proved to be unsustainable when introduced into developing countries. The basic feature of eco-development is that the means of improving the quality of life of a community should be sought within a framework bounded by the limitations - environmental, social and economic - governing the activities of the community. The means of achieving such aims should be determined by the principles of self-reliance; in other words, the technologies used should be decided and executed by the community and should not be dependent on outside events and forces.

DESIGN OF LIVESTOCK TECHNOLOGIES FOR THE TROPICAL THIRD WORLD

Goals and means

Improved technologies are essential tools in all forms of development. Past mistakes in technology transfer can be traced to the failure to understand the fundamental issues which must be considered before embarking on the design of technologies. Of these, the major one is: what are the constraints governing the design of the technologies? Are these the same for both developed and developing countries or are there basic differences that should be taken into account? Experience from the Third World tells us that while the scientific principles which underly technologies are the same, the technologies themselves are likely to be quite different. Some of the reasons for this statement are set out in Table 1.

These differences help to explain why there are conflicts concerning the strategies that should be applied when national governments, supported by international and bilateral technical assistance agencies (whose policies are largely determined by professionals from the industrialised countries), attempt to introduce innovations in the field of livestock research, technology transfer and training.

Table 1: Design of livestock technologies for industrialised and developing countries; goals and means

	Industrialised	Developing
Climate	Mostly temperate	Mostly tropical
Role of livestock	Specialised	Multipurpose
Target group	The rich	The poor
Resource base:		
Feed	Starch-protein	Fibre-sugars
Genetic	Improved	Native
Capital	High	Low
Labour	Low	High
Mechanisation	High	Low
Agrochemical	High	Low
Infrastructure	Good	Poor
Marketing	Good	Poor

Experience has shown quite clearly that it is counter-productive in developing countries to base these activities on the models that have been, or are currently being, applied in the industrialised countries. The conclusions of a recent evaluation report on Dutch assistance to the livestock sector in Third World countries (Netherlands Development Cooperation, 1987)

reveal how much time and effort have been wasted in these endeavours:

> **…"The animals (Dutch dairy cattle) were generally unable to adjust to local conditions; climate, feed and management systems all posed problems. The cattle were unsuited to small farmers" needs; they could not be used as draught animals and often suffered from disease stress, leg problems and infertility" ….**
>
> **…."the experience of twenty years revealed that the route (intensive livestock projects) had been ill-chosen".**

<u>THE "GREENHOUSE EFFECT"</u>

Discussing the issues of the world food crisis, population growth and renewable energy, Dumont (1989) stated:

> **"..Now an even more formidable threat has appeared on the horizon. Until recently, all forecasts (of crop yields) were based on the virtually certain knowledge that the world's various climates were invulnerable to major meteorological upheavals. That last lingering certainty has passed.…**
>
> **….it is now established beyond the slightest doubt that increased carbon dioxide levels in the air as a result of an excessively rapid increase in the use of fossil fuels, among other things, has caused the world's climate to warm up since the beginning of the 70s.**
>
> **….The warming-up process will raise the level of the sea and threaten the existence of all the great river deltas, especially those in Asia..**

…Increased temperatures have aggravated droughts and thus reduced the flow of the world's great rivers…

…Since the last ice age 18,000 years ago, the world temperature has risen by only four degrees. It is now feared that by the year 2050, only 61 years from now, the temperature increase could be between two and six degrees."

TOWARDS A NEW STRATEGY FOR SUSTAINABLE RURAL DEVELOPMENT

Matching production systems with available resources

The situation that has been described makes it obligatory to reorientate present production systems and to develop a new agricultural policy based on optimal use (instead of misuse) of the earth's natural resources. Such a policy must be rural, rather than urban, orientated and a notable feature of it will be the economic strengthening and increased independence of the small-scale farmer.

It has been proposed (Preston and Leng, 1987) that such a strategy be based on the development of agricultural systems which integrate production of food, fuel and fertilisers, and diverse livestock species, with emphasis on the utilization of:

- **Existing under-utilised local resources and wastes (e.g., crop residues, livestock excreta and agroindustrial byproducts)**
- **New resources derived from more efficient agronomic systems based on improved utilization of solar energy, soil, water, genetic diversity and people - which are the natural resources of the tropics. Specific reference is made here to the use of sugar cane and forage trees and shrubs as the principal elements in such a scheme.**

In the long and short term, it is hypothesised that the alternative to fossil fuel is in biomass derived from solar energy capture and that this is more viable and desirable than energy from nuclear sources, especially when environmental and social issues are taken into account. Furthermore, it is proposed that there need be no conflict, indeed the prospects are for complementarity, in the use of biomass to satisfy both food and fuel needs.

Such a policy presupposes a series of conditions, principal among which are the following:

- **crops and cropping systems must be chosen which permit maximum capture of solar energy and its conversion into biomass;**
- **optimum fixation of atmospheric nitrogen in relation to the nutrient needs of the selected crops and associated livestock systems;**
- **fractionation of the crops to satisfy dual needs of food/feed and fuel;**
- **the livestock components of the system should address the complementary needs of monogastric and herbivorous animal species.**
- **The overall system should:**
    - **be at least self-sufficient in, and preferably a net exporter of, energy,**
    - **not contaminate the environment,**
    - **not destroy natural ecosystems,**
    - **optimise employment opportunities, and**

- **promote a maximum degree of self-reliance.**

MEASURES THAT CAN BE TAKEN TO REDUCE EMISSIONS OF CARBON DIOXIDE AND METHANE

To the general policy described above, there must now be added a series of additional recommendations in order to address the specific problem of the "greenhouse effect". The following measures can be expected to lead to reduced emissions of methane and carbon dioxide. Not all are immediately executable, but they indicate what should be the long term goals in order to attain and maintain a balance between sources and sinks of carbon dioxide and methane.

- **Giving priority to the growing of crops which are most efficient in fixing carbon dioxide into biomass (eg: perennial tropical forage crops and trees).**

- **Encouraging agricultural production in the tropics of the Third World, instead of promoting self sufficiency in industrialised temperate countries. This is because food production systems in industrialised countries are highly dependent on fossil fuel-derived inputs. By contrast, most Third World tropical country systems employ animal and human power, rather than machinery, and they have a much greater potential for developing biomass-derived fuels. Means to this end would be the elimination of tariffs on food imports from the tropics, and of subsidies to farmers in the industrialised countries, and by applying an environmental tax to the use of fossil fuel since this is the main cause of the "greenhouse effect".**

- **In the tropical countries, wetland rice should be discouraged and more emphasis given to dryland cereal production for human consumption. Cereal growing for animal consumption**

in tropical countries should be actively discouraged, and emphasis given to perennial forage crops and forage trees as the basis of intensive animal production.

- **Grazing systems in the tropics should be actively discouraged, in favour of complete or semi-confinement of animals. This will permit planting of existing grazing lands with forests (especially multipurpose forage trees) and favour the greater use of crop residues as animal feed (instead of burning them).**
- **A massive programme is needed to promote strategic supplementation of ruminant diets in Third World countries in order to optimise rumen function (which leads to reduced methane and CO_2 production). This will also lead to increased production of food, or the keeping of fewer animals.**
- **Non-ruminant species (especially pigs, poultry, rabbits) should be favoured over ruminants as meat producers, since they produce less methane and carbon dioxide per unit of product.**
- **Low-cost biogas digestors must be an essential element in all units where livestock are confined.**
- **Human organic food waste must be recycled through pigs, and/or earth worms, instead of being allowed to ferment in land fills (giving rise to methane) or to be incinerated (producing carbon dioxide).**
- **Maximum support should be given to research and development efforts which will enable fossil-derived fuels to be replaced by biomass-derived fuels. Gasification of biomass to produce hydrogen and carbon monoxide (can be used directly as fuel or as substrates for**

chemical industry) would appear to be the most appropriate technology to promote.

REQUIRED INFRASTRUCTURE

Political or Technological Reform?

It is usually assumed that the first constraint to rural development is the need for reform of land tenure. However, it is becoming increasingly apparent that, with or without agrarian reform, there is no way that farming systems can absorb the "landless" labour force that exists in rural areas in most of the Third World. New solutions are needed and these must be based on proposals for technological as well as political change.

Tropical countries offer exciting possibilities for technological reform, because of the largely untapped potential for biomass production in regions blessed with abundant supplies of solar energy, high mean temperatures and rainfall. However, the realization of such potential wil require an original approach not only to the growing of the biomass but also its utilization.

Energy (with food as a byproduct) will be the key to such schemes, and the utilization of biomass as feedstock for a chemical industry will be as important as providing a substitute for present fossil-based liquid fuels. Rural industries based on "biomass refineries" promise to solve problems which are immediate, such as increasing rural employment, and of longer term, as is the prospect of developing a viable and safe alternative to non-renewable energy sources, both fossil and nuclear.

The need to reverse the greenhouse effect, coupled with the concern about the risks and the environmental contamination associated with the nuclear option, is a golden opportunity for the tropical regions to exploit their largely untapped resources inherent in the opportunity to use solar energy throughout the year. Existing rates of photosynthesis permit the capture of

10 times more energy than is presently consumed as fossil fuel (Hall, 1984: personal communication). This is being achieved with an overall global efficiency of only 0.2%. By contrast, a perennial tropical crop such as sugar cane fixes solar energy at 10 times this rate (2% annually) (Bassham, 1978). Tropical trees are almost as efficient and most have the added virtue of being able to fix ambient nitrogen in their root system.

STRATEGIES FOR MILK PRODUCTION SYSTEMS IN THE TROPICS

Where, in the above scheme, does tropical milk production fit and what strategy should be followed in establishing this kind of activity? The starting point must be an analysis of the actually and potentially available resources. There are no specialised tropical dairy animal breeds, other than the Riverine type of buffalo. Furthermore attempts to create them have not proved to be sustainable. The impact of the Australian Milking Zebu and of the Jamaica Hope, for example, has been minimal outside the immediate areas where they were developed.

The immediately available and numerically important cattle resources in the tropics are Bos taurus beef cattle. There are many advantages from using these as a basis for milk production through crossbreeding, foremost among which is the increase in productivity and in biological efficiency that results when milk and beef production are combined in the same animal. Converting existing extensive beef cattle systems in tropical countries into dual purpose milk-beef enterprises will increase their productivity and biological and economic efficiency. In ecological terms, this means a global reduction in methane production per unit of animal product, and the possibility of reducing total animal numbers (fewer, more productive animals consuming the same basic feed resources).

From the nutritional standpoint, the increase in productivity required in a dual purpose, as opposed to a specialised beef animal, does not entail substitution of local feed resources by

exotic (usually grain-based) “balanced dairy feeds” as is the case when specialised dairy breeds and systems are introduced (Netherlands Development Corporation 1987). What is needed is strategic supplementation with rumen activators and bypass nutrients, which can be met by judicious use of mostly locally available tropical agroindustrial byproducts (e.g., multi-nutritional blocks from molasses and urea, rumen micro-nutrients and bypass macro-nutrients from oilseed cakes and tree foliages (see paper by Leng, this conference)).

CONCLUSIONS

A new era is dawning in development strategy. Participation is mandatory in the setting of goals and identification of means. It is also becoming apparent that, because both the goals and the means are not the same, the initiatives taken by developing countries in establishing their own development strategies must not only be respected, but may also serve as stimuli for more effective cooperation between developed and developing countries.

Inadequate human nutrition is still the most immediate problem in most developing countries. But it is now being realised that the solution is not simply to increase productivity but to tackle more fundamental issues, foremost among which is the warming of the earth's atmosphere, caused by increased ambient concentration of carbon dioxide (mainly due to increased use of fossil fuels). This threatens, in the shorter term, to reduce crop yields and, in the longer term, heralds unmitigated disaster through flooding of river deltas.

Reversing the “greenhouse effect” will require promotion of solar efficient perennial crops, and forage trees, which simulate forest ecosystems and provide a sink for carbon dioxide. The biomass from these crops should lend itself to fractionation into low and high fibre components, the former being the basis of intensive confinement production of monogastric animals, while the latter can be converted into versatile energy-yielding substrates suitable

either as ruminant feeds or, through the process of gasification, as the basis of a chemical industry (hydrogen and carbon monoxide). Liquid and solid wastes can be recycled through biodigesters and earthworms with much reduced emissions of methane and carbon dioxide, compared with processing them through conventional oxidation lagoons and land fills.

In the field of livestock production, increasing emphasis must be given to systems which reduce methane emissions per unit of livestock product, at the same time permitting greater use of locally and potentially available resources. In this respect the two major approaches are: giving greater emphasis to monogastric species (especially pigs) as meat producers, and adapting presently inefficient extensive beef operations into dual purpose milk-beef systems.

These technologies, which are now being developed in Third World countries, will lead to more sustainable systems of livestock production, to employment generation, to increased availability of renewable energy and - most importantly -to a reversing of the "greenhouse effect". The challenge facing governments of industrialised and Third World countries alike is to be able to accept that development without either fossil or nuclear fuels is not only technically feasible but will bring with it much needed sociological and ecological benefits through the greater role that will be given to rural areas as the future source of both feed and fuel.

The implementation of these new strategies will require a greater appreciation of:

- **Communication as a means of promoting:**
    - **understanding of changing priorities,**
    - **awareness of common problems and the means of overcoming these, and**

- **Relationships founded on technological support rather than economic dominance.**
- **The concepts of ecodevelopment and self-reliance when designing and implementing technologies.**

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NUTRITIONAL CHARACTERISTICS OF TROPICAL FEED RESOURCES: NATURAL AND IMPROVED GRASSLANDS, CROP RESIDUES AND AGRO-INDUSTRIAL BY-PRODUCTS

by

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INTRODUCTION

Numerous studies and reviews have already been completed on this topic, e.g. Osbourn (1976), Minson (1976), Stobbs (1976), Balch (1977), Chenost and Meyer (1977), Jarrige (1979), Gohl (1981), Lane (1981), Preston (1982) and Devendra (1988). In the context of the present consultation, we will therefore restrict ourselves to reviewing the main characteristics of the tropical feed resources which should be taken into consideration when defining diets and feeding systems in accordance with the new principles of ruminant digestive physiology and nutrition.

RUMINANT INTAKE AND DIGESTION

The individual cow's daily production depends not only on its genetic characteristics and its stage of lactation but also a great deal on the quantity and quality of nutrients to its intermediary metabolism. This supply is the result of the voluntary intake and the nutrient density of feed intake.

Voluntary intake depends both on:

- **the appetite of the animal which varies according to the animal itself (age, physiological stage, former nutritional status, etc.) and to the environmental conditions (temperature, humidity, etc.) under which the animal is kept, and**
- **the specific characteristics of the feed.**

The voluntary intake of feed depends essentially on the rate of degradation of its digestible matter into particles of a size small enough to enable their passage from the reticulo-rumen to the lower gut. This degradation is achieved by means of the chewing process (eating and rumination) and the microbial fermentation which takes place in the reticulo-rumen. The cell wall content and the magnitude and nature of lignification of these cell walls are amongst the most important factors which govern the degradability and the rate of passage of a forage.

Good microbial activity will require:

- **adequate nutrition of the rumen microorganisms: energy in the form of ATP released from soluble and structural carbohydrates of the plant, thanks to the anaerobic fermentation; nitrogen in the form of ammonia generated by the hydrolysis of the fermentable nitrogen; minerals and vitamins;**
- **good chemical and physic-chemical rumen environment: pH (which should be as constant as possible and not below 6.5 to favour the cellulolytic microorganisms) and a regular outflow from the rumen. These conditions are not only dependent on the properties of the feeds but also on their rationing (number and frequency of meals, physical form of their presentation).**

Nutrients required at the tissue level for both maintenance and milk synthesis are supplied by the end products of rumen fermentation (amongst which are the volatile fatty acids (VFAs) and microbial cell proteins) and by the dietary nutrients which have escaped rumen degradation and are digested in the intestine. Depending on the level of production of the host animal, it may be necessary to provide, in addition to the forage, dietary supplements in order to meet its nutritional requirements. These supplements should be administered in a certain amount and should possess characteristics, such that the rumen ecosystem is not impaired and generates the proper amount and relative proportions of microbial protein, VFA energy and glucogenic energy.

In order to define an optimum diet it will therefore be necessary to choose the feeds according to the quality and quantity of energy and nitrogen available. These characteristics cannot be determined by the classical routine analysis. In addition to Crude Protein content and Organic Matter (or energy) digestibility it is important to know:

- **an estimate of intake, more particularly for those feeds which compose the basic part of the diet. A good indicator is the rate of their dry matter degradability in the rumen. This can be approached through the nylon bag "in sacco" technique which uses rumen-fistulated animals;**

- **an estimate of the respective parts of rumen degradable and undegradable ("by-pass") proteins available, respectively, for the rumen microorganisms and the host animal. This can be also approached with the nylon bag technique which can give an estimate of the extent and rate of protein fermentability. The French PDI (Protein Digestible in the Intestine) system (INRA, 1988) can distinguish between the various parts which are finally digested in the intestine, i.e. PDIA (Protein Digestible in the Intestine from dietary origin), microbial protein allowed by available fermentable N (PDIMN) and microbial protein allowed** by available fermentable energy (PDIME). The sum of PDIA + PDIMN on the one hand, and the sum of PDIA + PDIME on the other hand give, respectively, the PDIN and PDIE values of a feed. Balancing a diet by supplementing the basic feed with the appropriate supplementary feeds is achieved when PDIN and PDIE values of the diet are equal and meet the production requirements. This system is being adapted, for instance, to the Caribbean feedstuffs (Xandé and Trujillo, 1985).

- Data on energy sources: rate (see above) and type of fermentation. The slowly fermentable energy released from the structural carbohydrates or the more easily fermentable energy released from high digestible cell walls (e.g. citrus, beet or fruit pulps, which both favour a cellulolytic ecosystem. The fast degradable carbohydrates of “sugar type” (molasses) or of “starch type” (cereals, roots and tubers, banana) which both hamper the cellulolytic ecosystem (drop in pH). The end products of the former are essentially C2 whereas those of the second favour C3 VFA. Other important information, but of course difficult to predict, is the good timing of the release of NH_3 and ATP for optimum microbial nutrition and thus synthesis and microbial activity. Finally, an assessment of the undegraded part of energy in the rumen (e.g. rice polishings or maize, rather than wheat or cassava) usable in the intestine for the tissue requirements (glucogenic function) is also important (Preston, 1982; Van Es, 1985).

All these considerations are undoubtedly more important in tropical than in temperate regions even if the levels of animal production are lower. In fact, shortages of nitrogen (tropical feeds also contain less by-pass protein) and of digestible cell-wall energy may occur quite often in tropical countries. It is therefore important to be able to choose the proper missing components among the other locally available resources. As already discussed in several instances, supplements of the tropical basic diets have often more than an additive effect on both intake and animal performances (Preston, 1982; Van Es and Taminga, 1987).

We will briefly distinguish between the basic resources which compose the main parts of the diet and the other various resources which can supplement them.

The former are pastures and green fodders which are of course the principal natural ruminant feed. They are also crop residues, including the fibrous agricultural residues (FAR) which can be used as a substitute (partly or entirely) for herbage in those populated regions like South East Asia where land must firstly be devoted to production of food for man. Another group is the perennial food crops (e.g. sugarcane, bananas), and also roots and tubers which were formerly grown for man and are now more and more considered as feed, either for the dry season or even as the basis of the diet for new feeding systems.

Table 1. Main nutritional characteristics of the principal categories of tropical feed resources.

Feeds	**Rumen fermentation**		**Observations**
	Energy	**Nitrogen**	**Utilization**
Pastures	slowly fermentable	fair CP content	-fair intake
Green fodders			-lignified
Forages	VFA - C_2	fermentable	-rumen function and rumination
			Basis of diet
Crop residues:	slowly fermentable	very low CP content	-increased OMD and intake with treatment
straws			-need fermentable N + PDIA
stovers			
canetops			Basis of diet
Feed crops:			-need fermentable
sugarcane	slowly) fermentable	low CP content	+ PDIA nitrogen

(whole) Foliages - tree	quickly) fermentable	very high CP	Basis/supplement -rumen function
crops including			-aa sources (PDIA)
Leucaena,	C_2 - C_3	unfermentable*	-good intake
Glyricidia, etc.		(by-pass)	Supplement/Basis
Agro-industrial byproducts:			
energy			
molasses	easily fermentable	low N	
	(“sugar” type)		Supplement/Basis
pulps (citrus)	easily fermentable	low N	
	(“cell wall” type)		
energy + N			
bran/polishings	fermentable +	unfermentable	Supplement
	Lipids LCFA	N source	-PDIA + bypass
			energy, glucogenic
nitrogen			
oil cakes + seeds		high CP	
animal/fish	Lipids	PDIA a.a.	Supplement
NH_3 - urea		fermentable	industrial NPN

*** Further research is needed regarding the tannin effect on digestion(enzymatic) in the intestine**

The other category is roughly made-up of the agro-industrial and various by-products which can be utilized only as part of the diets.

We will now consider the way these feed resources can be utilized in the appropriate combination so that:

- **intake of the basic components is maximized,**
- **animal performances are optimized, and**
- **cost of diets is minimized.**

Although pastures and green fodders are the principal natural feeds for ruminants, there are also other feed resources which can be used as substitutes during the dry season (e.g., crop presidues), supplements (agro-industrial by-products: cereal brans, molasses, oilcakes, etc.) or as the basis of the diet (sugar cane, roots and tubers, bananas).

GREEN FODDERS, HERBAGES AND PASTURES

It is well recognized that the tropical herbaceous and shrub plants become high in lignified carbohydrates and low in total nitrogen when they mature. In addition their mineral content is low and unbalanced; phosphorous is amongst the most frequent deficient macro-elements.

The digestibility of tropical forages decreases at a lower rate than that of temperate ones but this decrease starts earlier and from a lower value at the young vegetation stage (Chenost, 1975; Evans, 1977). As a result, tropical grasses, and to a lesser extent legumes, always have a lower digestibility than the temperate ones (Minson, 1976) as shown in Table 2. In fact, the high content and the type of encrustation of lignin in the plant tissues and cell walls and the low N supply to rumen microbes are reasons which lead to a slow rate of breakdown and passage of particles to the lower gut and reduced intake of tropical grasses.

However, except in the case of natural pastures in dry tropical areas, tropical pastures have a tremendously high dry matter productivity. This productivity enables maintenance of high

stocking rates (carrying capacity) as shown in Table 3.

The yields of tropical C4 grasses (e.g. Digitaria decumbens) responds linearly to annual rainfall (or water supply when irrigated) when fertilized with nitrogen up to 400 kg N/ha (Salette, 1970). Nitrogen fertilization however does not increase the animal's daily production since it has very little or no effect on digestibility and voluntary intake.

Milk production per area unit can thus reach high levels, thanks to the stocking rate, but with low individual production per animal, as shown by numerous authors quoted by Evans (1977) (Table 4). Such low daily milk production levels (seldom higher than 12 kg) may hamper the duration of the lactation curve.

Table 2. Examples of digestibility, intake and rumen fermentation by sheep of some tropical grass hays. (from O. Kawamura *et al.*, 1985)

Nature of grasses(*)	**Regrowth number**	**Vegetative stage**	**Dry matter intake g/kg LW 0.75**	**Dry matter digestibility (per cent)**	**Crude Protein content (per cent DM)**	**ADF**	**VFA mm/100ml**	**C2 percent**	**C3 VFA**
Green panic	1	flowering	47.7	58.9	10.2				
	2	heading	45.9	53.4	13.5				
	3	heading	52.9	54.4	11.9				
Sudan grass	1	flowering	42.0	53.7	11.9				
	2	vegetative	50.7	55.0	15.6	37.5	5.62	75.1	13.0

	3	vegetative	48.0	58.0	14.9	to	to	to	to
						49.1	8.96	82.6	18.2
Rhodes grass	1	vegetative	44.2	56.3	10.0				
	2	vegetative	42.4	60.7	13.2				
	3	flowering	47.4	59.6	12.2				
African millet	1	vegetative	49.5	60.7	14.0		10.24		
Italian Ryegrass	1	heading	70.1	72.5	13.6	28.1	12.24	70.1	22.3
	2	heading	59.1	58.6	11.1	41.8	10.20	71.6	21.0

(*)wilted and air driedADF = Acid Detergent Fibre; VFA = Volatile Fatty Acids; C2 = Acetic Acid; C3 = Propionic Acid.

Many studies have shown that trying to increase individual production by exploiting the grass cover at an earlier stage of growth is wasteful and uneconomic. A recent study on buffaloes has also lead to the same conclusions (Wanapat and Topark-Ngarm, 1985). In fact, the loss in DM production/ha is not compensated for by the very small benefit, in terms of DOM intake, which could be expected from a faster turn-over.

Whereas a 4,500 kg milk lactation needs, in addition to a typical temperate forage-based diet, an average of 150 g concentrate for each kg of milk produced, the same level of milk production requires an average of 300 to 350 g concentrate in the case of a typical tropical forage-based diet. Such amounts are uneconomic (except when concentrates are subsidized) and illogical (substitution effect of concentrate depresses the DM intake of forage). It is

therefore necessary to resort either to an improvement of the basic diet or to design a strategy of supplementation taking into account other local feed resources (see below).

In areas where rainfall is higher than 750 mm per year, it is possible to oversow natural pastures with legumes which, most of the time, are not present in the primary grass cover. The effect of legumes is two-fold: firstly fixation of substantial amounts of N and therefore increase of the production of the associated grasses, and secondly an increase in the feeding value of the grass cover resulting from the higher N content and by-pass protein, the higher OMD and intake of legumes. A lot of research work has shown the importance of fodder legumes (Table 4) on the individual cow's daily production. The strategy to be finally adopted regarding the type of pasture (pure grasses versus grass/legume association) is however not only a nutritional problem but also an agronomical and managerial one.

But tropical green fodder, which represents the cheapest sources of forage, cannot in general ensure high individual milk secretion levels. The main limiting factors are intake and N content and quality.

CROP RESIDUES

The fibrous agricultural residues (FAR) represent a considerable potential forage resource in the populated countries where land must be devoted to human food production as a priority. A comprehensive review of their potential in the developing countries and of the strategies for expanding their utilization has been achieved respectively by FAO (1985) and IDRC and ICAR (1988).

Table 3. Carrying capacity and milk production per hectare from various pasture systems (from Stobbs, 1976, quoted by Jarrige, 1979).

Pasture system	Stocking rate (cows/ha)	Milk production (kg/ha/year)
- unfertilized grass	0.8 – 1.5	1,000 – 2,500
- grass-legume	1.3 – 2.5	3,000 – 8,000
- nitrogen fertilized grass (+P, S, K)	2.5 – 5.0	4,500 – 9,500
- nitrogen fertilized grass, irrigated (+P, S, K)	6.9 – 9.9	15,000 – 22,000

Table 4. Milk production from tropical pastures without supplementary feed (extracted from Evans, 1977)

Pasture	Stocking rate (cow/ha)	Breed	Milk yield	
			kg/cow/day	kg/ha/yr
Unfertilized pastures				
P. maximum	**1.1**	**Jersey**	6.8	2,667
M. miniflora				
P. maximum	**1.0**	**Jersey/Criollo**	6.9	2,667
D. decumbens	**1.5**	**Friesian/Zebu**	6.9	3,760
Grass-legume fertilized pasture				
P. maximum/Glycine	**1.3–2.5**	**Friesian**	12.4–13.7	4,954–8,221
D. decumbens/Centro	**1.7**	**Friesian/Zebu**	7.3	4,530
Nitrogen fertilized pure grass				
D. decumbens	**2.5**	**Jersey**	6.8	6,014

D. decumbens	6.9	Friesian/Zebu	10.9	17,408
D. decumbens	8.0	Jersey	6.5	22,466

Amongst the world's total crop residues maize yields the largest amount and wheat, rice and paddy and pulses each yield about half the amount of maize. The remainder consists of sorghum stovers, barley straws, sugarcane tops and leaves, roots and tubers, oil plants stovers and foliage (Kossila, 1985). They are still underutilized as feed resources, except in Asia where they form the first component of the ruminants' diet.

Their feeding value is limited by their poor voluntary intake, low digestibility and low nitrogen, mineral and vitamin content. In addition they are very slowly fermented in the rumen. In fact, they consist essentially of lignified structural carbohydrates, since they represent the dead aerial part of the mature plant after harvest.

The use of FAR as cattle feed has generated considerable research work in the last 20 years but unfortunately much less development application. However, they can represent the basic part of ruminants' diet provided:

- **conditions for their good cellulolysis are met (rumen activity), and**
- **additional nutrients required for productive functions (host animal), e.g. PDIA and energy escaping rumen fermentation are properly supplied (do not impair the above condition as stated in para. II).**

Their better digestive utilization can be achieved either through an appropriate supplementation (legumes, molasses, fruit pulps, poultry manure, urea, etc.) or chemical pre-treatments (urea/ammonia treatments) which both facilitate the microbial breakdown of the cell-walls. Appropriate supplements which enable a good cellulolysis can be chosen among the local feed sources on the ground of the characteristics listed in Table 1: the appropriate

fermentable N supply can be of natural (poultry manure) or industrial (urea) origin; the fermentable energy (of the "digestible cell-wall" type) is typically fresh grass or good quality foliage and, of course, all the easy digestible agro-industrial pulps, e.g. citrus, pineapple, etc. The breakdown of FAR can also be improved by chemical treatments (sundstø1 and Owen, 1984) among which urea-generated NH_3 is probably the technique which best fits in with the socio-economical conditions found in tropical developing countries where inputs must be kept at the lowest level possible.

Treated or not, FAR must be combined with feed supplements which provide adequate nutrients to the rumen microorganisms. The former, however, still require to be known with a better accuracy than at present. Recent research works (Silva and ørskov, 1988; Ramihone, 1987) have shown the importance - in addition to NH_3-N - of true protein sources on the cellulolytic microbial growth. This is another reason for supplying any cheap protected protein source (e.g. legume trees and foliages, ricebran), which, as seen above, are necessary for the production requirements of the host animal.

FOOD CROPS

Various perennial food crops which were formerly grown only for human consumption are now more and more considered as feed sources for the dry season and even as the basis of feeding systems. The main ones are sugarcane, cassava, banana, etc.

Amongst the various reasons for such their increasing use, two are probably most important. The first is the tremendous dry matter productivity/ha of these crops. The second one lies in the fact that, as opposed to conventional fodder crops, their nutritive value is not affected by the age of the plant which has already reached its stage of maturity. Their exploitation is therefore very flexible and easier than that of herbage.

1) The most typical example is probably the sugarcane, exploited as a whole plant. Sugarcane could play the same role in tropical animal production as the forage maize - whole plant - in the temperate countries. First considered in experiments by Preston in the 1970's, the sugarcane (whole plant) is typically the addition of two opposite types of forage components: structural carbohydrates of low and slowly digestible energy and soluble carbohydrates (sucrose) rapidly fermentable. In addition its N content is very low.

Whole sugarcane-based systems have proven to be technically and economically a very attractive solution for small to average dairy or dual purpose units in sugarcane producing countries where areas for fodder pastures are limited. As described by Preston and Leng (1978) the deficient nutrients may essentially be provided by locally grown (or available) feed resources:

- **fermentable N (PDIN) by green fodder or crop foliages and leaves (e.g. those of cassava) or by urea, (industrial NPN source);**
- **“by-pass energy” by rice polishings and/or roots, tubers (cassava) and fruit (bananas - banana rejects);**
- **unfermentable nitrogen (“PDIA”/“by-pass N”) by legume-trees namely Leucaena leucocephala, Gliricidia, Erythrina, and when necessary by oil cakes, e.g. cotton seed cake.**

2) Cassava (Manihot esculenta) is another fodder crop of great interest as a feed resource (Devendra, 1977). Its tubers are a valuable energy source which can also provide glucose at the intestine level as its starch can partially escape the rumen fermentation. Its leaves, exploited either as a green fodder (several cuts before harvesting tubers have proved to be still compatible with a satisfactory tuber yield) or, at the time of harvesting, the tubers are valuable

sources of both PDIN and, to a reasonable extent, PDIA.

3) Another interesting plant is the banana, either considered as a whole plant (when blown down by tropical winds and hurricanes) or as fruit (starch source) when considering the discarded bananas which remain available on the premises of the conditioning exportation units (Le Dividich et al., 1976). The banana as a basis of the diet is more adapted to beef production in view of its high starch and poor N content. As seen above it may however remarkably complement sugarcane. The whole plant can also be envisaged as the basis of the diet for milk producing animals.

AGRO-INDUSTRIAL BY-PRODUCTS

They can be classified into 4 groups:

- **By-products providing essentially easily fermentable energy through digestible cell-walls, starch or sugars. They may constitute the basis or the major part of the diet. They derive mainly from sugarcane, citrus, roots and tubers, bananas, coffee…**
- **By-products which are mainly used as a source of supplementary protein: oil-seed cakes, animal wastes from slaughterhouses and fisheries, by- products from pulses, single cell proteins.**
- **By-products providing both energy and protein: eg: cereal milling by-products, brewer's and distiller's grains and whey.**
- **other by-products coming from fruit, bakery and other food industries which provide various kinds of nutrients.**

All these by-products have been reviewed by various authors (Chenost and Meyer 1977, IDRC and ICAR 1988). We will therefore restrict to a brief account of the more important ones taken as examples.

<u>Molasses</u>

This is a feed which is rapidly and entirely fermented in the rumen. Between 10 and 30% of the diet, as is traditionally the case there is no particular problems with molasses for all types of livestock. However when the diet is based on molasses (eg: >70%) the behavior of cattle is different and the management of the herd must be more careful (Preston and willis 1974). A small amount of fibre is vital for ensuring the normal physical function of the rumen. Non-protein nitrogen is essential for the development of the micro-organisms of the rumen. Furthermore the animal responds dramatically to small amount of protein like fish meal, which can escape the rumen fermentation (Preston 1985).

However it has never been possible to incorporate as high levels of molasses in the diet of lactating cows as in the case of fattening cattle. The reason is that diets high in molasses lead to insufficient amount of glucose and glucose precursors (low propionate and high butyrate) in the end products of digestion (Leng and Preston 1976).

Molasses which is an excellent carrier for urea as a source of non protein nitrogen for ruminants can be more easily used as a supplement and distributed to small farmers when is part of solid multinutrient blocks (Leng 1984, Sansoucy 1986, Sansoucy et al 1988).

<u>Citrus and sugarbeet pulps</u>

Due to the high digestibility of their non lignified cell walls they favor, as opposed to molasses, the cellulolytic activity of the rumen. Due to the relatively moderate rate of fermentation (as

opposed to sugars) they also represent good carriers of NPN and ensure an efficient microbial synthesis (synchronization of both ATP and NH3 releases). They can constitute the major part of the diet as well as an excellent energy supplement for diets based on fibrous crop residues.

Oil cakes and seeds and by-products of animal origin

They have been comprehensively reviewed in the 1988 IDRC and ICAR's publication. They constitute the largest source of supplementary protein. As mentioned earlier in this paper, the assessment of their potential use as protein supplement will be based on the degree of degradability of their nitrogen in the rumen.

As they represent a source of foreign exchange and of high quality protein for human and non ruminant animals, their use as protein supplement for ruminants should be considered against the local availability of legumes and or legume trees.

Cereal milling by-products

They are very well known and their use is expanding. Their major asset is the fact that they supply at a time, moderately fermentable energy, dietary protein and neoglucogenic nutrients. As an example, rice polishings can play a remarkable role in balancing sugarcane based diets.

CONCLUSIONS

As a main concluding remark and as clearly observed by Preston and Leng (1987), the tropical basic feed resources have in common the fact that they are poor in nitrogen (namely in protected dietary PDIA) and rich in carbohydrates. These carbohydrates are however either structural and slowly fermentable or too easily fermentable compared to those of the temperate fodder plants, rich both in cell wall type and in less fermentable type of energy. As a result,

taken alone or in combination with each other, they will be fermented in the rumen at very different rates. In addition there is another drawback in that fermentable N (predominant in the main tropical feedstuffs) may also be released too quickly and not in time with the energy. Supplementing tropical feeds with crop residues, feed crops and agro-industrial by-products, will therefore have to take into consideration not only the above described characteristics but also the kinetics of release of the various nutrients. Attention to the rationing aspects will be of major importance.

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FEEDING STRATEGIES FOR IMPROVING MILK PRODUCTION OF DAIRY ANIMALS MANAGED BY SMALL-FARMERS IN THE TROPICS

By

R.A. Leng

INTRODUCTION

Milk is an important component of diets for all humans as it is high in essential amino acids that are most likely to be deficient in diets based on vegetable protein. Although milk is a high-cost source of protein and fat relative to vegetable sources, it is readily saleable particularly in the more affluent urban areas of developing countries. Improving milk production is therefore an important tool for improving the quality of life particularly for rural people in developing countries.

Milk production systems in tropical countries are diverse. At the one extreme the systems are similar to those in most industrialised countries and are based on cows of high genetic potential given "high quality feeds" which include fodder crops/silages and grain and protein concentrates. Milk production per cow is extremely high and technological inputs are high. At the other extreme are systems which are used by the vast majority of small farmers in developing countries and are based on low inputs and productivity per cow is relatively low. These small-farmer systems vary from ones in which cows or buffaloes are fed on crop residues, agro-industrial by-products and roadside grass to beef cattle grazing tropical pastures that are milked once a day, with the calf having access to the dam for the other half of each day. In the latter systems, the pastures available to these 'dual purpose' animals are typical of most tropical grasslands and are relatively low in protein and digestibility.

Every conceivable system between these extremes is used in various parts of the world. However, the small farmer on low milk production systems are those with the greatest potential for improvement and are the target of most aide programmes. In the discussion presented here, the strategies for improving milk production from cows/buffaloes fed tropical pastures, crop residues or fibrous agricultural by-products are discussed.

On these feed resources, overall productivity is low, animals reach puberty at a late age (often 4 years) and inter-calving interval is often 18–24 months, resulting in a small number of dairy animals in a national herd being in milk at any one time. A strategy for improving milk production in these systems has therefore two components. The first is to improve reproductive efficiency of the dairy animals and secondly to improve milk yield and persistency.

The greatest scope for improving a country's milk production is through a strategy which targets improvement of reproductive performance. This cannot be achieved however without increasing milk production per animal. Reducing age at first calving from 5 to 3 years and inter-calving interval from 24 months to 12 months by better feeding management will at least double the number of animals being milked at any one time. In addition, because the same feeding strategy that improves reproductive performance also increases milk production, the improved production per animal is also increased.

FEED RESOURCES AVAILABLE TO SMALL DAIRY FARMERS

The small farmers of developing countries have limited resources available for feeding to their ruminant livestock. They do not have the luxury of being able to select the basal diet but use whatever is available at no or low cost. The available resources are essentially low digestibility forages such as tropical pastures (both green and mature), straws and other crop residues and

agricultural by-products which are generally low in protein.

The major criterion for improvement in production is to optimise the efficiency of utilisation of the available fodder resource and not to attempt to maximise animal production. There is little point in knowing the "energy" requirements of a cow or buffalo for milk production, whose requirements are to be met from whatever crop residue is available. It is imperative, however, to understand the requirements for supplements that will provide nutrients that will optimise the efficiency of utilisation of that feed resource.

THE BASIC CONCEPTS

When considering how to optimise the utilisation of the available forages for dairy animals, two basic concepts must be applied as follows:

- **To make the digestive system of the cow as efficient as possible by ensuring optimum conditions for microbial growth in the rumen.**
- **To optimise production by balancing nutrients so that these are used as efficiently as possible for milk production without jeopardising the reproductive capacity of the cow.**

Any further increases in production may be obtained by the use of supplements of protein, starch and lipids to provide nutrients for milk production above those obtained when the efficiency of utilisation of the basal feed has been optimised. These supplements should be processed and must by-pass the rumen and become available for digestion in the intestine and in this way provide the nutrients in exactly the correct balance for additional milk production.

The two concepts can be implemented by feeding a combination of non-protein nitrogen (NPN), minerals and by-pass protein. The third component is a relatively new concept which suggests

that milk production, once the efficiency of utilisation of the basal feed resource has been optimised, depends upon providing nutrients needed for the components of milk, e.g. the quantity and balance of glucose (for milk lactose), protein and fat, in a form that will by-pass the rumen.

AN APPROACH TO IMPROVING NUTRITION OF LACTATING ANIMALS

The approach taken has been one in which urea/molasses blocks (UMB) have been provided to lactating ruminants to allow a slow, continuous intake of nutrients needed to optimise fermentative digestion in the rumen. By-pass protein supplementation is used to optimise the efficiency of use of absorbed nutrients. The development of both these strategies has gone along similar lines with testing under laboratory conditions being followed by testing on well managed farms and eventual trials under village conditions (see Leng and Kunju, 1989).

Over the last year, all Friesians imported into India and placed under the care of NDDB have been fed according to the strategies proposed (see Leng and Kunju, 1989). The 300 day lactational yield has been, on average, 6000 litres.

In addition, several thousand tonnes of a by-pass protein have been fed to cattle and buffalo under village conditions in various climatic zones. On the basis of this research and the experience gained, the largest feed mill in India producing 300–600 tons of feed per day (Amul Feed Mill, Anand) commenced the production of a new pelleted feed supplement containing 30% protein and with approximately 75% of the protein in a form likely to by-pass the rumen.

BACKGROUND - THE USE OF NPN AND BY-PASS PROTEIN IN RUMINANT DIETS

Definition

- **By-pass proteins are defined here as those dietary proteins that pass, intact, from the rumen to the lower digestive tract.**
- **Digestible by-pass protein is that portion of the by-pass protein that is enzymatically hydrolysed in, and absorbed as amino acids from, the small intestine.**
- **Over-protected protein is that protein of the by-pass protein that is neither fermented in the rumen, nor digested in the small intestine.**
- **Metabolisable protein is the digestible by-pass protein plus the digestible protein in the microbes that enter the small intestine.**
- **Fermentable carbohydrates are those parts of the feed carbohydrate that are degraded by microbial action in the rumen to volatile fatty acid (VFA) plus that entering into the microbes that grow with the energy (ATP) released when VFA are produced.**

Protein digestion in ruminants

In different production systems, ruminants consume many types of carbohydrates, proteins and other plant and animal constituents. All digestible carbohydrates are fermented to volatile fatty acids (VFA) plus methane and carbon dioxide by microbial action. Proteins are degraded by microbial enzymes in the rumen to give the same three end-products (i.e. VFA, CO_2 and CH_4) plus ammonia (see Figure 1). In all cases a proportion of the substrate metabolised by microbes is used for synthesis of the microbes.

The microbial fermentation of soluble protein in the rumen is an unavoidable consequence of the ruminant mode of digestion. In the absence of other forms of N, it ensures a supply of

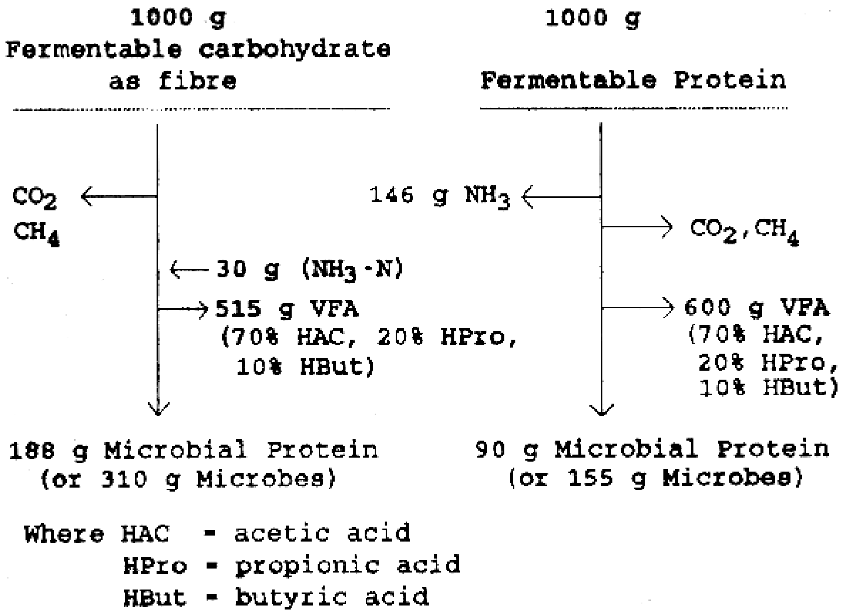
ammonia nitrogen for micro-organisms from which they synthesize the protein in their cells. Under many circumstances, it is a wasteful process because high quality proteins are broken down to ammonia, absorbed as such, converted to urea in the liver and this is excreted in the urine.

EFFICIENCY OF MICROBIAL GROWTH ON PROTEIN

Protein degradation to VFA leads to a relatively low availability of ATP ('energy') to rumen microbes and therefore protein that is degraded in the rumen is inefficiently used for the growth of micro-organisms. In comparison with carbohydrate when protein is degraded in the rumen, only half the ATP (the energy currency of the microbes) is produced in fermentation of protein relative to the same amount of carbohydrate.

The breakdown of carbohydrate in the presence of adequate ammonia and sulphur and other minerals supplied by, for instance urea/molasses blocks, results in more microbial protein being produced than from an equal amount of protein fermented in the rumen. This is shown diagramatically in Figure 1 and indicates that from a highly soluble protein such as leaf protein, less than 10% of the protein in the diet is available to the animal.

Figure 1. The breakdown of fermentable carbohydrates and protein in the rumen with the production of VFA and microbial protein.



Quite clearly therefore with readily soluble and fermentable protein; whilst little escapes the rumen if the protein is in high concentrations the protein to energy ratio in the nutrients arising from the rumen may be decreased.

Factors that influence the availability of by-pass protein

For a variety of reasons a proportion of the dietary protein passes from the rumen into the small intestine without alteration. On reaching the small intestine this by-pass protein is digested by enzyme hydrolysis and absorbed into the body as amino acid.

The conditions under which some dietary protein may escape the rumen for digestion in the lower alimentary tract include:

- **When a protein meal has been made highly insoluble by heat treatment.**

- **The protein meal contains tannins (2–4%) which bind to make an insoluble tannin - protein complex (Barry, 1985) which is not degraded in the rumen but is degraded in the abomasum/small intestine.**

- **Chemical treatment has been applied, e.g. formaldehyde treatment (Scott, 1970).**

- **When a relatively soluble protein meal is fed in very high quantites and is either in a finely ground form or is rapidly fragmented into small particles which move quickly through the rumen. For example, when clover or lucerne (that do not contain tannins) are fed at levels below 2.5% of liveweight (on a dry matter basis), it is probable that no dietary protein escapes to the lower tract. However, at levels above this, some protein escapes because of the rapid movement of digesta out of the rumen. The amount of by-pass protein can be as high as 30% of the total protein in the feed if this is highly digestible (D. Dellow & J.V. Nolan - unpublished; Nolan and Leng, 1989.).**

- **When heat is applied to a mixture of soluble protein and xylose, when a modified browning reaction can insolubilise the protein.**

Microbial protein synthesis in the rumen

Ammonia, peptides, amino acids and amines form the nitrogenous substrate for the synthesis of microbial cells but ammonia is the most important source of N for the microbes that ferment forages. Ammonia is used by many species of rumen micro-organisms as their sole source of nitrogen for protein synthesis (see Leng and Nolan, 1984).

This assessment of the role of ammonia in the rumen can be misleading if it is unqualified. Firstly some species of bacteria and protozoa commonly found in the rumen cannot grow or survive unless small quantities of peptides, amino acids or branched chain fatty acids are

provided in the diet and are present in low concentration in rumen fluid (Hungate, 1966).

A high level of rumen degradable protein in the diet may support high levels of all N-nutrients needed by bacteria and may cause specific populations of microbes to develop in the rumen as compared to diets where urea alone supplies the fermentable N.

A deficiency of rumen ammonia results in a low microbial growth rate which may reduce digestibility of fibre and lower intake of feed.

The requirements for ammonia for microbial activity

Estimates of the critical level of ammonia in the rumen fluid for efficient digestion has been reported to be as low as 50 mg N/1 or as high as 200 mg N/1. However, recent studies have shown that, when ammonia concentrations fall below about 200 mg N/1, the rumen, micro-organisms are inefficient and are likely to respond to dietary NPN supplements particularly to UMB (Krebs and Leng, 1984; Boniface et al., 1986; Sudana and Leng, 1986; Perdok and Leng, 1989).

Intake of straw by cattle has been shown to be increased by increasing urea levels in the diet until the level of ammonia reaches 200 mg N/1 (Boniface et al., 1986; Perdok and Leng, 1989).

Recent studies with buffaloes fed forage based diets showed that, given a period of access to molasses/urea blocks, these animals learn to modify their intake according to the protein content of the basal diet (Table 1).

Table 1. The influence of N content of the basal diet given to lactating buffaloes on the intake of a block lick based on molasses/urea (Leng and Kunju, 1989).

Group	Diet N content	Intake of block lick	Milk produced FCM	Liveweight changes

No.	(gN)	(g/d)	(kg/d)	(g/d)
1.	0	586	4.3	- 357
2.	30	256	5.7	- 455
3.	83	293	6.3	+ 276
4.	111	173	6.1	+ 89

Can the rumen microbes supply all the protein needs of the ruminant?

Even when ammonia and other nutrients are supplied, the quantities of microbes that leave the rumen in digesta do not supply sufficient protein to meet the needs for productivity in ruminants (i.e. moderate to high growth rates and milk yields). In such a situation, the deficiency symptoms indicate an insufficient supply of essential amino acids to the tissue. Under these conditions supplementation with a protein meal (which has a high content of by-pass protein) to supply additional dietary amino acids increases both the level and efficiency of animal production (see Preston and Leng, 1987).

Protein (or Amino Acid) Requirements of Ruminants

In the past, the protein requirements of ruminants and evaluation of the protein value of feeds for ruminants have been based on digestible crude protein (N × 6.25). This is now recognised as a misleading concept. The use of digestible crude protein has arisen largely because it was considered that cattle and sheep could obtain their essential amino acids from microbes produced in the rumen. This in turn led to suggestions that extensive use could be made of non-protein nitrogen in high carbohydrate feeds and that a special role of ruminants could be to convert non-protein nitrogen to high quality animal protein.

These have now been superseded by new concepts which take into consideration that when

amino acid requirements are high, insufficient digestible microbial protein is available from the rumen to meet these needs. It is now necessary to assess the requirements for N by ruminants in terms of the amount of ammonia (or NPN) and amino acids needed by the rumen microbes, and the amount of digestible by-pass protein needed by the animal to augment the total protein (amino acids) available to the animal and to create an efficient metabolism. The sum of the two sources of digestible protein represents the metabolisable protein.

Protein or amino acid requirements relative to energy requirements of ruminants are, however, influenced by a number of factors and cannot be stated with any degree of accuracy. The requirements are influenced by:

- **physiological state of the animal,**
- **rate of growth and milk production,**
- **body composition as influenced by previous dietary and health history,**
- **basal feed (particularly fat content),**
- **proportions of the different amino acids absorbed,**
- **patterns of rumen fermentation (i.e. acetate:propionate ratio),**
- **availability of volatile fatty acids,**
- **requirements for glucose for essential purposes,**
- **environmental heat or cold stress, and**
- **the extent of the work load of the animal.**

With all these unknowns, the need for by-pass protein under conditions pertaining to small-holder cattle can only be assessed in feeding trials aimed at developing response relationships. The effects of physiological state of the female goat on the utilisation of protein and, therefore its requirements, is well illustrated by the data shown in Figure 2.

Metabolisable protein Available to Ruminants

Metabolisable protein available is the sum of digestible dietary by-pass protein plus digestible protein from microbes reaching the lower tract. On most straw based diets the metabolisable protein is mainly of microbial origin (i.e. there is no by-pass protein in the diet). The amount of protein available therefore depends on the efficiency of microbial growth in the rumen.

This in turn depends on several factors:

- **the presence of all the essential nutrients in the balances and amounts needed by the rumen microbes to grow e.g. ammonia, sulphur, phosphorus, trace minerals, amino acids, peptides, etc.,**
- **a source of fermentable dry matter, i.e. the feed consumed,**
- **to a small extent the rate of digesta turnover and therefore feed intake. However, this depends on degradability of the feed, type of carbohydrate and the physiological status of the animal.**
- **buffering capacity of the rumen and pH of the rumen fluid which largely depends on diet, and**
- **the balance of micro-organisms in the rumen. If supplementation with carbohydrate promotes protozoal population this can actually decrease the protein to energy ratio in the nutrients available from the rumen (see Bird and Leng, 1985).**

As an example of how the balance of microbial protein to VFA energy can be altered in a cow given a straw based diet, the effects of an inefficient rumen (low rumen ammonia supply) and

an efficient rumen (optimum rumen ammonia) are shown in Table 2. (see Leng, 1982 for the assumptions and calculations).

The point is that the P:E ratio in the nutrients absorbed is altered according to how efficiently the rumen organisms are digesting the feed or how much by-pass protein there is in the diet.

Figure 2. The effects of physiological state on the intake and retention of nitrogen in goats fed oaten hay/lupins (11% crude protein) (Halais, 1984)

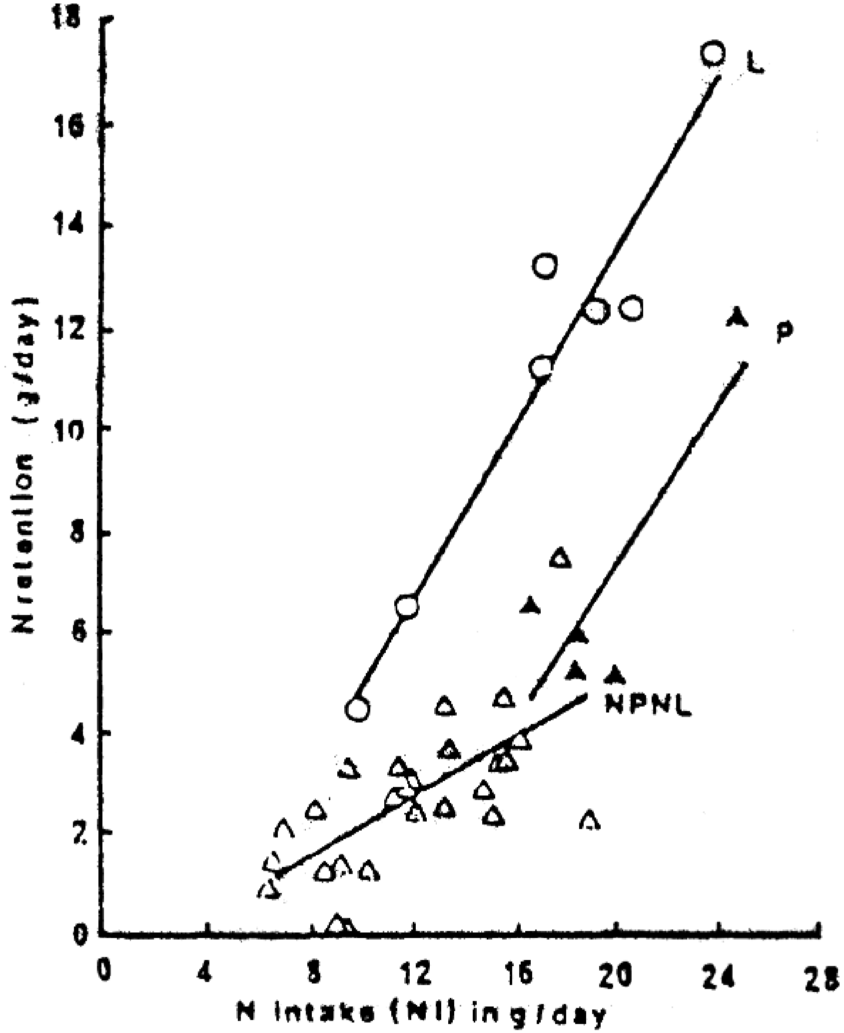


Table 2 The theoretical effect of feeding urea and urea plus by-pass protein on the P:E ratio in cattle. The values were calculated for a bovine consuming 4 kg of digestible organic matter without or with urea or with urea and 400 g of a by-pass protein source.

Rumen condition	**Microbial protein synthesised (g/d)**	**Total protein available (g/d)**	**VFA produced (MJ/d)**	***P/E ratio (g protein /MJ VFA)**

Deficient in ammonia	500	500	41	12:1
Sufficient in ammonia	1010	1010	30	34:1
Ammonia sufficient + 10% of the diet as by-pass protein	1010	1410	30	47:1

*** no consideration is taken here of the digestibility of the microbialor dietary by-pass protein**

<u>Effect of increasing ammonia concentrations in the rumen of cattle on N deficient diets</u>

In most situations, adding urea to a low protein diet, such as that based on a cereal crop residue, increases intake of the basal diet in addition to improving microbial growth and digestibility (Table 3).

Table 3. The effect of infusing urea into the rumen of a cow given straw based diets (Campling <u>et al</u>., 1962).

Diet	Straw DM Digestibility (%)	Intake of Straw (kg/d)	Theoretical* P:E ratio (g protein/MJ VFA
Straw	39	5.6	12:1
Straw +			
150 g urea	47	7.9	34:1

*** taken from Table 1.**

The potential effects of providing a UMB to ruminants on low protein forages (which is intended to provide urea and other nutrients) include the following:

- **Increased digestibility of straw**
- **Increased feed intake**
- **Increased absorption of total nutrients**
- **Increased P:E ratio in the nutrients absorbed**

The effects of supplementation of by-pass protein

Supplementing a diet of crop residues fed to cattle with a by-pass protein improves the P:E ratio in the nutrients absorbed (see Table 1 and 2). This has a large influence not only on the level of production but on the efficiency of feed utilisation (i.e. the amount of feed required per unit of milk production or growth, is lowered). Stated in another way, animals produce less metabolic heat when P:E ratios are well balanced to requirements. This is well illustrated by research shown in Table 4 where straw intake has been maintained constant and efficiency of utilisation of the feed is improved by supplementation. In other studies the increased efficiency is not readily discernible as the effect of such supplements is to increase forage intake (see Preston and Leng, 1987).

Table 4. The growth rate of calves (live weight 150 kg) given rice straw and supplemented with an oilseed meal (Saadullah, 1984).

Daily Supplement (g/d)	Straw intake (kg/d)	Liveweight-gain (g/d)	Feed conversion ratio (kg feed/kg gain)
0	3.8	84	46:1
200	3.8	371	11:1
400	3.8	373	12:1
600	3.8	508	9:1

RESEARCH ILLUSTRATING THE RESPONSES OF CATTLE TO UREA/MOLASSES BLOCKS AND

BY-PASS PROTEIN MEAL SUPPLEMENTATION

Growth studies

Jersey bulls (350 kg live weight) fed rice straw plus a concentrate (low in true protein i.e. about 15%) trebled their rate of weight gain when fed a molasses/urea block in conjunction with 1 kg of this concentrate (Table 5).

Studies with lactating cows/buffaloes

In ten villages, the average milk sold in the collection centres increased by 0.4–1.1 litres/day when the farmer made a molasses/urea block available to their dairy buffaloes (Table 6). Other trials showed that concentrate supplementation could be reduced without loss of milk production when a molasses/urea block was given.

Table 5. The effects of supplying molasses/urea blocks to cattle fed rice straw plus 1 kg 15% concentrate (Kunju, 1986).

	Straw intake (kg/d)	Block intake (g/d)	Live Wt. change (g/d)	Feed cost/kg gain (Rupee/kg)
No block	6.4	0	220	9.3
With block	6.8	530	700	3.7

Table 6. The observations on response of feeding block licks in villages (Kunju, 1986). The results show the milk or milk fat sold to the local collection centre (Kaira District Co-operative Milk Producers' Union Ltd., Anand, India).

Village	Milk (kg/d)		Milk fat (g/d)	
	pre lick	with lick	pre lick	with lick

Alwa	4.8	5.9	300	450
Punadhara	4.0	4.8	270	340
Fulgenamuwada	2.4	3.5	160	280
Hirapura	4.2	5.2	350	480
Bamroli (N)	3.6	4.2	270	380
Dehgam	4.3	4.7	310	350

More recently it has been demonstrated that feeding a meal high in by-pass protein (low in grain) as compared to a cattle feed concentrate based on traditional requirements increased milk production and live-weight gain without substantially influencing basal feed intake (Table 7).

The cattle were each fed 40 kg of green forage daily. The forage consisted of 60% legume (mostly lucerne/cowpea) and 40% non-legume (maize, sorghum/oats). The concentrates for cattle in group 1 were fed according to NRC recommendations. The cattle in group 2 were fed a protein concentrate based largely on solvent extracted protein meals demonstrated to have a high by-pass protein content. A major point here is that the animals in group I disposed of nutrients equivalent to 20–25 MJ of energy presumably through 'futile cycles of metabolism'. This additional metabolic heat production could have increased body temperature by 16.5°C if the animal had been in an environment where this extra heat could not have been dissipated. The feeding trial was conducted during the cool season but

Table 7: The effects of replacing balanced concentrates with a high by-pass protein pellet on live-weight change and milk yield of Jersey × Kankrej cows (M.G.P. Kurup, G. Kunju NDDB, India - pers. comm.).

Group	No./group	Crude Protein in	Intake of	Milk Yield	Live-weight

		supplement (%)	supplement (kg/d)	(kg/d)	change (g/d)
1	75	18	4.7	8.0	- 210
2	75	30	2.6	8.8	+ 202

clearly in the hot season feed intake could not have been maintained. Put another way, if the environmental temperature was critical for cattle in group II then the animals in group I would have needed to reduce their feed intake by 20 MJ ME.

CONCLUSION DRAWN FROM STUDIES IN INDIA

The efficiency of feed utilisation is enormously improved if the rumen of the animal has a healthy microbial population adequately supplemented by providing a molasses/urea block which often increases the intake of a basal diet. Adding a by-pass protein supplement will further improve the efficiency of utilisation of the basal feed resources but will also allow animals to maintain feed intake at high environmental temperatures and humidity. Conversely, the productivity of lactating animals can be maintained at a lower feed intake provided the rumen is made efficient and the animal's metabolism is made efficient by supplementing with a molasses/urea blocks and by-pass protein meal respectively.

CONSTRAINTS TO APPLICATION OF THE BY-PASS PROTEIN TECHNOLOGY

Even though the application of UMB/by-pass technology is highly promising, a few constraints are still to be overcome before it can be widely applied with confidence. Some of these are given below and indicate areas for intensive research:

1. **The information regarding the degradabilities of protein in all raw materials used in cattle feed are not yet available and may be quite variable depending on source, manufacturing**

conditions and presence of other compounds.

2. **Easy laboratory tests for protein degradability are still not available and there is still some considerable disagreement as to which method provides the best indication of the content of by-pass protein in a protein meal.**

3. **There are insufficient data from feeding trials available on milk production per unit input of by-pass protein under the systems commonly used by small farmers.**

4. **There are no response relationships for milk production for economic analysis of the feeding of by-pass proteins which covers at least two lactations. This is important as by-pass protein supplementation on these diets often improves the body condition of cattle and therefore reproductive performance. The second lactation after introduction of these systems may show the greatest economic response.**

5. **Many protein meals are undergradable in the rumen. However, their digestibility in the intestines may be very low. This applies particularly to protein meals with high tannin content. Such protein meals are not good sources of protein to the animal since much of the protein is lost in faeces.**

6. **For the most efficient utilisation of by-pass protein for production, the essential amino acid to total N ratio must be high.**

7. **The limits of responses to by-pass protein resides in the digestible energy content of the diet and at low digestibilities, high level feeding of a by-pass protein meal will result in amino acid degradation as an energy supply.**

PRACTICAL APPLICATION OF BY-PASS PROTEIN IN VILLAGE SOCIETIES

Feeding Friesian cows of high genetic potential for milk production - The National Dairy Development Board of India (NDDB) experience

Friesian cows of German origin were imported into India as potential mothers for the next generation of bulls for cross-breeding with indigenous cows. These animals were distributed to (1) NDDB farms with management and accurate recording of milk yield and (2) individual village farmers in cool environments. The NDDB farms, which are situated at Anand and Bidaj in Gujarat, are in areas with extremely high summer temperatures which often exceed 40°C and may at times exceed 50°C.

All animals are fed whatever forage is available and were provided with urea/molasses blocks and fed only a by-pass protein concentrate (30% CP) at 300–500 g/litre of milk production. All animals have thrived, most are now in their second lactation and where accurate records have been kept have produced between 6000– 6900 litres of milk per 300 day lactation with peak daily lactations often exceeding 30 1/day.

The point that has to be emphasised is that these animals were apparently relatively unaffected by the hottest period of the year and maintained milk production at a time when there is usually a marked reduction in milk yield. They were fed the available forage which varied from mixtures of rice straw and green oats/crops through to a mixture of rice straw and tropical grass. The practical observations support the more controlled research under institutional/laboratory conditions and indicate a major influence of balancing nutrition on amelioration of heat stress in lactating animals.

Amelioration of Anoestrous in Village Buffalo/Cattle

A major problem associated with milk production in village societies is that the "non-descript"

animals which are by far the majority of dairy animals are often fed the poorest feeds particularly in early life and between lactations. The reason for this is that without the cash flow that comes from milk and with no rapid cash return on their outlay, village people (who always experience cash flow problems) are not prepared to purchase supplements.

In general, in developing countries, cattle and buffalo often calve for the first time at 4–5 years of age and have an inter-calving interval of up to two years. Infertility is therefore a major problem.

The improvements in growth rates mediated by the feeding strategies discussed here also suggest that reproductive rate may be similarly improved. A demonstration trial was established to test this hypothesis. Within two village societies, cattle and buffalo were selected that had exhibited (over an 8–12 month period) either infantile genitalia (buffalo heifers) or no ovarian activity in mature cows/buffaloes. These animals were provided with molasses/urea multi-nutrient blocks over the hot summer months and 90 % of these animals came into oestrous after 3–4 months (Table 8). These studies have also been supported by studies of grazing cows supplemented with molasses/urea blocks in Africa which have shown a marked decrease in the lactational anoestrous period (Table 9).

The implications for improving milk production of these discoveries is extremely large. Decreased age at first calving, together with decreased inter-calving interval, may increase the total number of animals lactating at any one time by 2 or even 3 fold, this in turn will increase milk production from the national herd by the same increase.

Table 8. The effects of providing molasses/urea blocks to cattle and buffalo on reproductive activity (John, NDDB, personal communication). The animals were owned by small-farmers and had been diagnosed as anoestrous (adult animals) or having infantile genitalia (buffalo heifers) and had been in

this condition for 8–12 months. The farmers were given molasses/urea multinutrient blocks at no cost. The period covered was the hottest part of the year.

	No.	No. of animals coming into oestrus		
		before 120 d	after 120 d	never
Crossbred cow	12	11	1	0
Adult buffalo	18	17	1	0
Buffalo heifers	39	28	6	5

Table 9. The effect of providing a molasses urea block (UMB) to grazing cows (Gobe Ranch, Ethiopia) on the length of the post- partum or lactational anoestrous period (ILCA, 1987).

	Post-partum anoestrous period (days)		
	UMB supplement	no supplement	diff.
Continuous suckling	132	199	67
Restricted suckling	113	159	46

TREATMENT OF CROP RESIDUES TO IMPROVE DIGESTIBILITY

The treatment of crop residues with alkalis to improve digestibility is a well researched and established technique. Feeding treated straw as compared to untreated straw considerably improves ruminants productivity (see Sundstøl and Owen, 1984).

Simple techniques based on ensiling the wet straw (50% moisture) with 3–4% urea are well established and could be applied under village conditions. However, these techniques are only being accepted slowly or are unacceptable to small farmers for a variety of reasons which vary from country to country and within districts in the same country. The main constraints to implementing straw treatment as a means of improving milk production in small-farmer systems are economic, sociological and logistic.

Economic considerations

Small farmers invariably have a cash flow problem and purchase of urea is restricted generally for crop production. Often plastic covers for the straw are costly and impractical. In addition, the returns for use of urea on a rice crop must be offset against the income from milk.

Sociological considerations

Often the most appropriate time for treatment of crop residues is at harvest time, when most the family are involved in long hours of work and have no time to treat straw. The availability of water is often a constraint. In most countries this would be carried in urns by the women from a distant source. These wives/daughters of small farmers generally have very full working days. Often, for security or convenience purposes, straw is stored in or close to the residence of the family and the smell of ammonia is highly unacceptable and may lead to eye disorders particularly in children. Finally, wet straw is much more difficult to store, preserve and feed to the cattle.

A major constraint is that farmers, from experience, have a fairly accurate annual feed budget. The main benefit from treated straw comes from increased feed intake and therefore the budget has to be adjusted. Failure to do this often results int he farmer having to purchase expensive straw which will be economically disadvantageous.

Conclusion

For straw treatment to be successfully accepted by small-farmers in developing countries the methods must be made easy, low cost and must have low labour inputs. It seems that, for the foreseeable future, straw treatment is unlikely to develop as a national strategy but will be used by the larger farmers particularly those that can afford to buy labour.

RESEARCH NEEDS

For the implementation of the new feeding system, more feeding trials need to be carried out in which response relationships of milk production/weight change can be correlated with level of by-pass protein feeding. However, some of this can be left to individual farmers who can be instructed to slowly increase the level of protein meal until they are satisfied with the response. They will automatically take the most economic option and the important point to stress is that farmers must have access to the supplements.

The influence of these feeding strategies on reproductive performance needs further research as it is likely to have the greatest effect within a country.

The feed processing technology should be modified in view of the new system with a view to increasing, in processing, the by-pass protein content of a pelleted feed. A suitable feed formula based on the nutrient supply, processability and economics of feeding needs to be developed, for use with the important basal feeds available to small-farmers.

There is a wide gap today in this technology between the research nutritionists who use only single ingredients or a combination of two or three protein meals and the practical feed manufacture who uses a variety of feeds compounded on least-cost basis. Since many developing countries have large quantities of protein meals in the country then technology development to ensure its efficient utilisation should be a matter of priority. In countries where the oilseed meals are unavailable, the potential of forage trees containing tannins, or the treatment of forage tree leaves to protect the protein need to be developed.

THE FUTURE

The challenge for the scientist in many developing countries is to how best combine in a diet

for dairy animals the available green forage, crop residues and agro-industrial by-products with the available protein resources and molasses/urea block to optimise milk production. It is likely that the availability of protein for dairy animals is likely to be the primary economic constraint, it is therefore necessary to develop new protein resources (e.g. aquatic plants, tree crops) and to find ways and means of protecting the protein from degradation in the rumen whilst remaining of high digestibility is an urgent priority.

Increasing milk production following optimisation of the efficiency of utilisation of the basal feed resource

The “Greenhouse effect”, that is the warming of the Earth's atmosphere because of increased content of carbon dioxide and methane, will in the future require a reduction in production of these gases. Methane produced by ruminants probably contributes about 25% of the increase in global methane concentration in the atmosphere (which is 1 % per year at present) and this source of methane can be reduced by decreasing the number of ruminants in the world. This will necessitate a move to increase production per animal to maintain and increase this source of human food. This increase per animal will need to be made within the constraints of the available feed resources.

Milk is essentially water, lactose, protein and fat. To boost production of milk from animals fed available forages above that stimulated by the optimum level of by-pass protein plus urea/molasses blocks, it will be necessary to supplement well balanced mixtures of amino acids (from by-pass protein) and lipids (as unreactive LCFA combined with calcium to form soaps) and by-pass starch.

The role of dietary fat in the nutrition of ruminants has traditionally been looked upon as a means of increasing the energy intake of ruminants without a proportional increase in the

quantity of feed consumed. A strong case for inclusion of fats in ruminant diets was made by Milligan (1971) on the basis of the energetic efficiency of incorporation of dietary long chain fatty acids (LCFA) into tissue LCFA of fattening animals. Kronfeld (1976,1982) proposed that an optimal balance between aminogenic, glucogenic as well as lipogenic nutrients is required for maximal efficiency of milk production and prevention of ketosis in highly productive dairy cows. Theoretically, this should be achieved when, amongst others, exogenous LCFA contribute 16 % of the total ME intake (Kronfeld, 1976). Similar levels of LCFA inclusion in the diet of lactating cows, was determined to result in an optimal efficiency of nutrient utilization for milk production by Brumby et al. (1978).

Very little information is available, however, on the influence of dietary LCFA on the efficiency of nutrient utilization by growing and lactating ruminants, especially when they are fed roughage-based diets. Although results reported in the literature are highly variable, generally it is believed that the inclusion of more than 4–6% fat in the diet will result in a reduced digestibility of fibre in the rumen and sometimes a reduced DMI (Kronfeld, 1982; Moore et al., 1986), unless these lipids are offered in a form which makes them relatively inert in the rumen.

Calcium salts of LCFA (Ca-LCFA) are such a source of ruminally inert LCFA (Palmquist and Jenkins, 1982; Jenkins and Palmquist, 1984) and have been shown to increase milk production by dairy cows when used as a feed supplement (Palmquist, 1984). Interactive effects of dietary LCFA with nutrients other than fibre have received little attention.

An interaction between dietary LCFA and protein meals has been found and on low protein diets, the benefits of dietary fat are only apparent when a by-pass protein is fed (van Houtert and Leng, 1986).

The quantitative importance of these possible nutrient interactions is unknown in dairy animals

fed forage based diets but since the nutrients in milk arise from long chain fatty acids, amino acids and glucose, research is now being aimed at developing a supplement which provides directly to the animal.

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FEEDING RIVERINE BUFFALOES FOR MILK/DUAL PURPOSE PRODUCTION

by

A.M. EL-Serafy

INTRODUCTION

Of the world total of about 138 million buffaloes (Jasiorowski, 1988), riverine buffaloes represent 70% with the concentration in India (76 M) Pakistan (14 M) and Egypt (2.4 M). Jasiorowski (1988) and Mudgal (1988) point out an increase of about 11.2% in the number of the river buffalo type between 1983 and 1986, indicating an increasing awareness by farmers of the importance of the animal in their economic life and as an integral part of the farming system.

Proportions of buffalo milk and meat respectively in the world total production increased from 5.5% and 0.8% in 1976 to 6.8% and 1.0% in 1986. In Asia and the Pacific countries, total milk production from buffaloes in 1985 was about 31 million tonnes (91% of total) (Mudgal, 1988) with India alone producing about 22 million tonnes. Corresponding values for meat production are 1 million (80%) and 0.3 million tonnes in Pakistan. In Egypt, buffaloes produce 65–70% and 45–50% of total milk and meat respectively, (Central Agency for Statistics, 1986).

For many decades however, research for development was slow, scattered and uncoordinated and failed to achieved meaningful results. Consequently, it was believed that the low fertility and low production levels are inherent traits of the species. Fortunately, coordinated research in the past 25 years in Egypt, India, Japan and Taiwan supported the theory that low production levels are related to poor management and to poor nutrition in particular.

The main aims of this paper are:

1. **to compare the characteristics of the digestive physiology and nutrition of the buffalo and the cow, and**
2. **to describe an improved feeding/management package for enhancing the production of milk and meat.**

COMPARATIVE DIGESTION AND NUTRITION OF RIVERINE BUFFALOES AND CATTLE

There is no difference in the digestive tract between the buffalo and the cow, the four-pouched stomach and the rest of the gastro-intestinal tract being the same in both species. The rumen in cows and buffaloes is well adapted to utilize the cellulosic matter and the main fermentative compartment proceeds the main site of digestion, allowing the maximal use of fermentation products.

From a functional point of view however, there might be a difference between the riverine buffalo and the cow in ability to digest poor quality roughage, e.g. rice straw (Ranjhan, 1988). The reason for this difference, reported from feeding trials, is not quite understood although differences in rumen bacterial growth rate between species were reported by Zaki El-Din et al. (1985) as a result of feeding the same roughage diet with or without added urea and/or molasses. The ability of the buffalo to consume more DM from rice straw than the cow could further explain the difference in digestion (Devendra 1987).

In Egypt, research on comparative digestibility and efficiency of feed utilisation between buffaloes and cows is limited. It has been reported that local buffaloes and cows digest concentrates and good quality roughages, like berseem hay, equally well. With poor quality roughages like rice straw however, the buffalo excelled the cow in digesting DM and CF (El-Ashry 1988; Saied Mahmoud, personal communication). With regard to the efficiency of feed utilisation for meat production, the buffalo steer calves produced more meat per unit of feed intake than either local steers of native or Friesian breeds (El-Ashry et al., 1975).

Research reports from India indicated the superiority of riverine buffaloes over cows in lignin turnover and that was due to animal size being responsible for greater digestionin buffaloes than cows (Mudgal, 1988). The results also show that TDN output/input ratio varied from 6 to

30% and protein output/input ration from 5 to 40%, indicating that buffaloes fed on straw and a grain-based diet were more efficient than cows. With regard to comparative utilization of energy for milk production, it has clearly been shown that maintenance and production requirements were higher in Murrah buffaloes than in Brown Swiss x Sahiwal cows, indicating that cows were more efficient in utilizing metabolizable energy for milk production than buffaloes (Mudgal, 1988).

FEEDING/MANAGEMENT OF RIVERINE BUFFALOES

Feeding from birth to weaning

A project was started in 1973 and continues at Ain Shams University, Faculty of Agriculture to study the effect of improved feeding management on the performance of buffalo calves during pre-and post-weaning phases of growth. The accumulated results from this project (El-Bassioni, 1983; El-Serafy et al., 1982) and from other research stations in Egypt were summarized by El-Serafy and El-Ashry (1989).

In general it was concluded that, to achieve maximum benefits from rearing calves on milk replacers, a package of management is required, namely to feed restricted amounts of replacers (4 kg liquid divided into two meals), to have fresh water available, to avoid using antibiotics in milk replacers, to introduce a mash starter from two weeks, to offer good quality berseem hay leaves ad libitum and to rear calves in a well ventilated barn, always using a dry bed of rice straw.

Feeding buffalo males for growth

From weaning to about 150 kg body weight, male calves require special attention in formulating rations to promote maximum tissue growth. A highly digestible pelleted starter (70 to 75 % TDN

and 15 to 17% DP) is essentially required to achieve about 0.7–0.8 kg ADG (EL-Ashry et al., 1981). The ration concentrate to roughage ranges between 50:60 or 60:40 on a DM basis, with good quality berseem hay making up at least half of the roughage (El-Koussy 1981). Comparable ADG values for buffalo calves at the same age/weight reported in the fifties and sixties were much lower (400–600 g: Ragab et al., 1966).

Different roughages fed to male calves during growth have shown the superior effect of rice straw, compared to wheat or bean straws (Afifi, 1977). Their results showed that calves required 4.42, 4.68 and 4.80 kg feed DM to produce one kilogram gain.

Rice straw contains more ligno-cellulose bonds and ash than wheat or bean straws (Van Soest, 1987, personal communication) and its TDN value is less than the other two straws (Abou Raya, 1967). A possible explanation for better efficiency of utilization by buffalo calves is that the rumen cellulolytic micro-organisms in buffaloes are more capable of breaking these bonds, making hydrolyzed glucose units available for VFA production (Abou Akkada and El-Shazly, 1966; Zaki Eldin et al., 1985)

Feeding for fattening of buffalo males

Two fattening practices of male buffalo calves are recognize in Egypt:

1. **Fattening from 200 to 350 kg, over a short fattening period of about 4 months, and**
2. **Fattening from 250 to about 500 kg over a relatively longer period of 10 to 11 months (called bitello).**

The first practice produces relatively juicier meat but the second is the main practice because of its high dressing yields.

The overall ADG during fattening is usually between 800 to 900 g/d, depending on the level of concentrates, being higher with concentrates level in ration over 50 % of the diet in which the main roughage as rice straw (Afifi, 1977). In feedlot fattening operations (Shehata et al., 1973), ADG was 800 to 1000 g when the concentrate portion of the ration was 75% and when 1 kg concentrates was offered for each 50 kg live body weight.

Carcass measurements

Although in fattening trials different ratios of concentrates to roughages were used, the dressing percentage ranged from 50 to 60 %, depending on the weight at slaughter, being higher than 52% at slaughter weights above 400 kg. Also, high dressing percentages, meat:bone ratios and carcass-fat are usually associated with high levels of concentrates (Table 1).

Table (1) Dressing and bone-less meat percentages of buffalo calves slaughtered at different weight categories.

	Feeding groups*					
Item	**I**	**II**	**III**	**IV**	**V**	**Overall average**
Calves slaughtered at 300 kg						
Dressing %	53.3	53.5	57.4	50.2	47.1	52.3
Boneless meat %	83.2	81.7	82.8	79.9	81.7	81.8
Calves slaughtered at 400 kg						
Dressing %	57.1	54.7	54.1	54.0	57.6	55.5
Boneless meat %	81.2	82.5	82.7	81.9	83.4	82.3
Calves slaughtered at 500 kg						
Dressing %	59.8	60.2	59.7	60.6	54.4	59.9

Boneless meat %	79.3	82.1	84.0	83.0	78.2	81.3

*** Feeding groups I to V corresponds to levels of Napier grass of 5, 10,15,20 and 25%, respectively on DM basis.**

In conclusion, the recommended feeding regime for growing male buffalo calves from 90 to 200 kg live body weight consists of a 50:50 concentrate to roughage ratio on a DM basis. The concentrate portion should be highly digestible pellets containing 65–70% TDN and at least 15% DP, while the roughage portion is made up of 2-cut berseem hay and rice straw (50:50 ratio). Intake in this growing period was calculated as 3% of body weight. For fattening purposes, the rations should contain between 65–80% concentrates.

Feeding of growing/pregnant heifers

Raising of a good buffalo heifer is a prerequisite for achieving a high-yielding buffalo cow. The characteristics of a good heifer in Egypt (El-Ashry, 1988: El-Fouly and Afifi, 1977) are to weigh 350–370 kg at 16–18 months of age at which the heifer reaches sexual maturity, exhibit regular oestrus cycles and to be ready for mating in order to deliver her first calf at 27–28 month of age (460 to 480 kg weight).

From weaning to about 180 kg, heifers require the same special attention as was described in feeding males. About 2 kg/100 kg body weight of the pellet starter are required to achieve about 700 g ADG. A typical ration during this growing phase (average weight 125 kg) is composed of 2.5 kg of starter concentrate and 1 kg each of berseem hay and rice straw. Calculated intakes of nutrients in this ration are as follows: DM 4.1 kg, DM % of body weight 3.2, TDN 2.5 kg, DP 0.455 kg, ME/kg $W^{0.75}$ 229 kcal. Mudgal (1988) reported ME for maintaining

buffalo heifers as 188 kcal/kg $W^{0.75}$, while Arora (1988) reported a value to 206 kcal/kg $W^{0.75}$ for maintenance and growth.

It has been shown that late-pregnant buffalo heifers need an extra 0.5 kg corn per day, in addition to the previously mentioned requirements. Aboul Ela (1988) concluded that resumption of cyclic activity post-partum in buffalo cows is influenced by feeding in late pregnancy and early lactation.

Feeding lactating buffalo cows

On a DM basis, buffalo's milk contains about 41 % of total ingredients as fat and is thus characterized by a relatively high energy content, which should be carefully considered in the ration fed. A standard water buffalo cow weighing 500 kg, in her 3rd lactation, producing 7 kg/d milk for 300 days with average 7% fat requires 2 kg TDN and 400 g DP for maintenance plus 750 g TDN and 80 g DP per kg milk produced.

In Egypt, different concentrates and roughage ingredients are used to make up rations for lactating buffalo cows. Common concentrates which have been examined include cereal grains, cane molasses, cotton-seed cake, horse bean, soybean, linseed meal and sunflower seed. Common roughages include berseem hay; rice, wheat and barley straw; wheat and rice brans; rice hulls and water hyacinth hay or silage. The main green forage in winter is berseem (Trifolium alexandrinum) and its hay in summer.

In practice, a mixture of concentrates (60% TDN, 14% DP) is prepared in a cube form and comprizes yellow corn 23–25%, undecorticated cotton seed cakes 25–40%, wheat bran 10–15%, rice bran 10–15%, sugar cane molasses 3–6% and common salt plus lime stone 1.5%– 2.5%. In winter, the feeding system of dairy buffaloes depends on green berseem and rice straw for dry,

non-pregnant or early-pregnant buffalo cows. In summer, on the other hand, berseem hay replaces green berseem and green maize (darawa) is offered as a source of available vitamins (El-Ashry, 1988).

Several research trials were conducted to evaluate different roughages and concentrates for lactating buffalo cows. The ultimate goal of these trials was to introduce cheaper feed ingredients at maximum rate in the rations. The relatively cheaper roughages, mechanically-treated non-classical roughages like cotton stalks and corn cobs, were sprayed with sugar cane molasses to improve their utilization by lactating buffalo cows (El-Serafy, 1968). Although hazardous and expensive, NaOH treatment significantly improved the utilisation by lactating buffalo cows of poor quality roughages (rice and wheat straws and cotton stalks) (Abou Raya, 1967). The level of roughages in rations for lactating buffaloes has been generally accepted as 50% of total DM.

Research on the use of cheaper sources of nitrogen indicated that the urea can replace up to 50% of total nitrogen of rations for lactating buffaloes with no adverse effect on milk or fat yield (Khattab et al., 1981).

The level of concentrates in rations for milk production from buffaloes has a significant effect on milk and fat yields and the efficiency of dietary energy utilization (El-Ashry et al., 1975; the results are summarized in Table 2. Their data indicate that the efficiency of dietary utilization for milk production was significantly greater in winter than in summer. The level of 50% concentrates was more efficiently utilized for milk energy or protein but more than 60% concentrates in the ration reduced milk fat.

When intake is equal, the efficiency of utilization of the above feed ingredients for milk production is not different within a class of feedstuff. Mudgal (1988) discussed several factors

affecting feed requirements and utilisation by buffalo cows and indicated that in dry subtropic regions temperature, shade, water requirement and disease are most important factors.

Table 2 Effect of level of concentrate and season on efficiency of dietary energy utilisation for milk production

Feeding season	Concentrate level %	Net efficiency of use of dietary energy %
Winter	**0**	65.2
	25	68.0
	50	67.6
Summer	**0**	60.2
	25	60.9
	50	62.0

Feeding bulls for production and draught

Feeding riverine buffalo bulls for production and draught is not common practice in Egypt. For doing some light work and for exercise, 5–6 year old breeding bulls are used to operate waterwheels ("sakia") for irrigation. The share of buffaloes in farm work was calculated as less than 8% of annual working hours regardless of farm size (Soliman, 1985). Requirements of breeding/draft bulls were calculated by Ranjhan & Pathak (1983).

OTHER MANAGEMENT ASPECTS IN REARING RIVERINE BUFFALOES

The following practices are used in improved management systems in Egypt:

- **supplementary minerals and vitamins when animals are consuming dry feeds (summer feeding),**

- spraying animals with water twice/d in summer (June-August),
- tethering fattened calves or lactating buffaloes and loose-housing for heifers,
- use of locally available materials for making sheds (the roof for sheds is made of rice straw sandwiched between two light-wood-framed bamboo mats),
- detecting oestrus with the bull twice daily,
- artificial insemination (using fresh semen) 10–12 hrs from the first natural mating,
- using mechanical milking machines, and
- regular (weekly) veterinary checks and assistance of the veterinarian in heifers delivering their first calf.

FUTURE OUTLOOK

Research should concentrate on biotechnology aspects such as super ovulation, embryo transfer, hormonal treatments to increase milk production and manipulation of rumen micro-organisms for better utilisation of ligno-cellulosic bonds in high-fibre-containing roughages. With increasing demand for milk and the noticeable decrease in the area of forage every year, there is an urgent need for cross breeding, possibly with a smaller but more productive strain. Otherwise buffaloes could loose ground to the efficient crossbreds from exotic cattle.

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FEEDING SWAMP BUFFALO FOR MILK PRODUCTION

by

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INTRODUCTION

In South-east Asia, the water buffaloes are predominantly of the swamp type. They are raised in small herds of 1–5 on small farms (2 to 5 hectares). Buffalo raising in this region cannot be considered as a distinct enterprise, rather it is an integral part of crop (mainly rice) production. Apart from serving as the main source of farm power, their integral roles in the small farm system include being the producers of farm manure, the removers of farm wastes, the living money savers (which act as the most reliable alternative source of farm income) and to exhibit the social status of the owners. Beef is no more than a by-product from buffaloes which are too old or not fit for work. Milk hardly plays any significant role in the small farm systems.

Traditionally, care of buffaloes is the responsibility of farm children. The animals are kept within the village, usually under the house, at night and spend the day-time hours grazing in the harvested paddy fields, along roadsides and on the edges of cultivated plots. In the rainy season, the animals are tethered on a small plot of land set aside for this purpose and supplemented with cut-and-carry grasses and/or rice straw. Minerals, except salt, are not

generally offered. Water supply, for both wallowing and drinking, becomes a problem in many areas, particularly in Northeast Thailand during the dry season.

Breeding of village buffaloes is accomplished without human planning. It may occur at night or during the daytime when the animals are released and begin to mix with the village herd, as they do at the grazing or watering sites. This implies that mating does not generally occur during the rainy season when most of them are engaged in land preparation. This, along with other unfavourable factors such as the typical low reproductive rate of the species, high calf mortality and insufficient feed supplies, makes the herd productivity low and has led to a gradual decrease in size of the national herds in various countries (Bhannasiri, 1980; Toelihere, 1980). In order to cope with the increasing demands for draught power and beef, Frisch and Vercoe (1984) have outlined a strategy to increase both numbers and productivity of the herd in the region. Among these, ways of improving reproduction efficiency, draught output, growth rate and milk yield are discussed, taking into account the limitations set by the fact that the main feeds are made up of cereal straws and crop by products.

REGIONAL INTERESTS IN IMPROVING BUFFALO PRODUCTIVITY IN SMALL FARM SYSTEMS

The importance of buffalo as the indispensable support to crop production in small farm systems and the need to improve its productivity have been well realized by researchers and administrators of various institutions since the early seventies. A comprehensive overview, highlighting such interests, has been given by Soni (1985).

In Thailand, the Cooperative Buffalo Production Research Project, which was initiated in 1971 to join the inter-institutional efforts in solving two key problems of the decrease of buffalo number in the national herds and the reduction of mature body weight and size, has subsequently become the National Buffalo Research and Development Center, jointly

undertaking research responsibility for several aspects for improving the buffalo productivity under small farm conditions.

The research thrust includes health care, reproductive physiology and artificial insemination, genetic improvement, nutrition and the integration of milking buffaloes into the farming system in some specific regions. The research results are regularly published in its annual reports and exchanged with its regional counterparts by means of regular publishing of "Buffalo Bulletin" under the support of the International Buffalo Information Center and the Regional Buffalo Development Network or through the "Buffalo Journal" of Chulalongkorn University. Recent technical information obtained, particularly on the digestion of fibrous residue feeds and on the feeding and management of buffaloes for milk production, will be highlighted in the following sections.

COMPARATIVE CHARACTERISTICS OF THE PHYSIOLOGY OF DIGESTION AND NUTRITION OF BUFFALO AND CATTLE

As with other ruminants, the buffalo has a remarkable ability to refine coarse roughages through rumen fermentation, leading to the formation and utilization of various essential metabolites for its nourishment. Anatomically, the rumen and reticulum of the buffalo are similar to those of cattle. However, the rumen of the buffalo, accounting for over 80 percent of the stomach capacity, is heavier than that of cattle and is 5–10 percent more capacious (Sengar and Singh, 1969). The buffalo omasum has lower tissue weight and capacity but the same number of laminae, having a narrower inter-laminar space than cattle. The abomasum of buffalo differs slightly in the distribution of cellular elements in the mucosa and its digestive ability is adversely affected by high air temperature than in the case of cattle (Chalmers, 1974). With respect to comparative physiology of digestion of buffalo and cattle, agreement has been reached in results from several studies in the particular aspects of:

1. **the rumen of the buffalo calf becomes functional at an earlier age;**
2. **the microbial populations, bacteria and protozoa, are more numerous in the buffalo rumen;**
3. **the changes in the microbial populations, as affected by changes in season and thus proportions of food constituents, are more marked in the buffalo rumen;**
4. **the rate of passage of feed through the rumen of the buffalo is slower, allowing a longer retention time and exposure to more microbial action;**
5. **ammonia and soluble nitrogen disappear from the rumen fluid of buffalo more rapidly than from that of cattle, suggesting that the former utilizes protein more efficiently than the latter.**

All of these characteristics tend to indicate that buffaloes have a higher efficiency of digestion than do the cattle. In his review of research results, derived from a large number of studies in the Indian subcontinent, Gupta (1988) concluded that buffaloes were more efficient converters of coarse roughages than cattle. His conclusion has been substantiated by the results of a number of trials which have shown higher concentrations of some metabolites in the rumen of the buffalo and higher digestibilities of dry matter, organic matter and crude fibre when compared to cattle. However, contradictory findings have also been regularly reported by a number of researchers such as Moran (1983). Chalmers (1974) expressed her doubts on such the claims due to the facts that :

1. **a number of trials were involved with inadequate numbers of experimental animals;**
2. **studies should take into account differences in the kind of feeds, feeding levels, age and type of animals, rumen volume, rate of passage of feed, adequacy of water supply, deficiencies of vital feed constituents, management practices and so forth;**
3. **rumen content of various metabolites is always dynamic, with synthesis and breakdown occurring all the time. Variations in techniques used in sample preparation and/or chemical analysis would lead to different conclusions.**

In her view, enough evidence indicates that there were only small differences in the efficiency of rumen digestion of fibre in cattle and buffaloes. However, she agrees that buffalo can utilize poor quality roughages more efficiently than cattle. A limited number of studies along these lines have been recently conducted with swamp buffaloes compared to Zebu cattle. Wanapat (1984) compared the dry matter degradability of 7 intact protein feeds by using the nylon bag technique on swamp buffalo and Brahman cross bulls being fed rice straw or urea-treated rice straw with 200 g/d fish meal. It was found that the DM degradability in buffalo was slightly higher than that in cattle, regardless of types of rice straw fed, at any 4-hour period ranging from 0 to 24 hours after suspension (Table 1).

Table 1. Dry matter degradability (%) of protein sources in the rumen of cattle and water buffalo.

	Duration (h.)									
Source	**0**		**4**		**8**		**12**		**24**	
	RS	**UTS**	**RS**	**UTS**	**RS**	**UTS**	**RS**	**UTS**	**RS**	**UTS**
Fish meal										
Buffalo	14.9	15.7	16.7	33.1	24.4	27.1	31.5	29.6	37.7	41.5
Cattle	15.5	16.3	26.3	29.0	25.3	27.1	29.4	27.9	36.0	39.6
Soybean meal										
Buffalo	23.5	33.9	29.4	44.5	34.2	31.3	33.8	38.5	66.7	66.1
Cattle	25.8	28.9	31.4	39.7	29.5	37.0	42.1	42.4	54.5	63.1
Leucaena leaf meal										
Buffalo	11.4	25.3	20.3	22.9	23.5	20.1	28.1	30.7	32.0	48.6
Cattle	9.0	23.3	26.5	26.1	23.5	21.9	26.0	35.2	32.5	44.9
Water hyacinth leaf meal										
Buffalo	24.9	27.6	21.4	27.5	27.5	23.3	28.7	32.4	29.9	41.7

Cattle	24.3	27.8	26.3	31.3	28.3	24.8	24.7	29.0	30.3	36.1
Cassava leaf meal										
Buffalo	11.4	21.8	16.9	20.5	19.2	19.2	24.6	27.5	34.0	43.1
Cattle	14.7	16.9	19.2	21.1	22.4	21.8	21.5	24.7	35.2	45.2
Sunnhemp leaf meal										
Buffalo	13.0	15.6	17.8	22.4	16.4	16.1	20.1	23.6	30.8	36.0
Cattle	10.2	21.9	13.1	20.1	20.1	18.4	21.0	22.1	24.5	27.7
Rice bran										
Buffalo	8.3	15.8	18.5	37.5	24.9	30.6	29.3	39.7	45.3	49.6
Cattle	8.7	10.8	18.2	28.5	26.4	28.4	32.4	33.7	40.3	47.5
Buffalo	15.3	22.2	19.5	29.8	24.3	24.1	28.0	31.7	39.5	46.7
	�6.4	�7.1	�5.0	�9.0	�5.8	�5.9	�4.5	�5.8	�13.9	�9.7
Cattle	15.5	20.8	23.0	28.0	25.1	25.6	27.9	30.7	36.2	43.5
	�7.1	�6.6	�6.3	�6.6	�3.3	�6.1	�7.3	�6.9	�9.4	�11.0

RS = rice straw, UTS = urea-treated rice strawFrom Wanapat (1984)

The same group of workers (Chanthai et al., 1986) measured the metabolites in the rumen of a buffalo and a bullock being fed rice straw or urea-treated rice straw. It was shown that the rumen NH_3-N and rumen pH in the buffalo were higher than those of bullock (5.81 v. 4.49 mg % and 7.31 v. 7.01). The total VFA's were, however, significantly lower in buffalo than in cattle regardless of dietary treatments (Table 2).

Table 2. Comparison of NH_3-N, pH and total VFA between cattle and buffalo fed on rice straw (RS)

and urea-treated rice straw (UTS).

Item	Feed		X�SEM
	RS	UTS	
NH_3-N, mg %			
Cattle	0.47	8.51	4.49�0.26[a]
Buffalo	1.28	10.34	5.81�0.26[b]
X�SEM	0.88�0.26[a]	19.43�0.26[b]	
pH			
Cattle	7.06	7.04	7.05�0.02[a]
Buffalo	7.24	7.38	7.31�0.02[b]
X�SEM	7.16�0.02[a]	7.21�0.02[a]	
Total VFA, mole/1			
Cattle	68.86	87.86	78.33�1.40[a]
Buffalo	58.72	72.38	65.55�1.40[b]
X�SEM	63.76�1.40[a]	80.12�1.40[a]	

a,b, Value in the same row or column under appropriate headings with different superscripts differ (P<0.05).

From Chanthai et al. (1986)

With a higher quality roughage, Mahyuddin and Jalaludin (1986) compared the rumen metabolites and dry matter and nitrogen disappearances by nylon-bag techniques in 4 Kedah-

Kelantan cattle and 4 swamp buffaloes being fed guinea grass (Panicum maximum) ad libitum with free access to mineral blocks. It was demonstrated that the rumen pH was lower in buffalo while the VFA's level was higher than those in cattle. The rumen NH_3-N levels were similar in both species and stayed at a low level after reaching a peak at 3 hours after feeding. The in situ degradability of DM and N of guinea grass showed an increasing trend throughout the first five 10-hour incubation periods and levelled off afterwards to 72 hours of incubation. The DM and N degradation rates of buffaloes (4.00±0.40, 3.90±0.55% h) were significantly higher than those of cattle (3.59±0.37, 2.83± 0.50% h).

On rice straw-based complete diets containing a 2% increment in crude protein ranging from 6 to 22 percent, Devendra (1985) compared the nitrogen utilization in 4 buffalo bulls and 5 Kedah Kelantan cattle by a balance trial. It was found that the buffaloes had higher N retention due to a significantly lower urinary nitrogen excretion than did the cattle. In both species, N intake was significantly correlated to apparently digestible nitrogen and N balance. The author stated that the DCP requirement for maintenance were 1.50 and 1.37 g/$w^{0.75}$kg/day for the buffalo and cattle, respectively.

No firm conclusion can be drawn from the available data on whether or not buffalo can digest crude fibre more efficiently than cattle. The state of knowledge, however, strongly indicates that buffaloes can perform better on the poor quality roughages such as those that are available in small farms throughout Asia, namely the fibrous crop residues. In addition, the available data indicate that the buffalo utilizes protein more efficiently than cattle. This indication lends itself well to the possibility of improving buffalo productivity under the limited resources of small farms.

FEEDING AND MANAGEMENT OF BUFFALOES FOR MILK PRODUCTION

The swamp buffaloes are generally recognized as poor milkers when compared to the riverine breeds. The average milk yield ranges from 1.0 to 1.5 kilograms per head per day over a 270 to 305 days lactation (Castillo, 1978; Wejaratwimon et al., 1979 and Thawinprawat et al., 1985). Their potential for milk yield seems not to be greatly improved by improved feeding and management conditions (Frisch and Vercoe, 1984). However, they are of great value as the basic genetic stock from which animals with a greater potential for meat, milk and draught may be developed. Cross breeding of the swamp with the riverine buffaloes has been one of the ways to exploit the milking potential of the existing meat/draught animals in Thailand as well as in other Asian countries (Table 3). Tumwasorn (1981) conducted a comprehensive review on milk production and draught ability of the swamp-Murrah crossbred and reported that the average milk yield of the crossbred was 4 kg/d (2.0–6.3 kg/d) over the 256-day average lactation period. In his separate case study covering 6 herds of the Murrah crossbred cows in a village, he reported an average milk yield of 6.9 kg/d over a 242-day lactation. Working ability of the crossbred has been indirectly reported in terms of body weight and is not very meaningful.

Table 3. Milk yield of different buffalo breeds.

Breed	Lactation length (days)	Average daily milk yield (kg)	Note
Local (Swamp)[1]	236	1.94	Partly work
Murrah�local[1]	277	3.73	Partly work
(M � L) � Murrah[1]	292	5.20	
Murrah[1]	237	6.60	
Swamp � Murrah[2]	256	4.00	

Swamp � Murrah[2]	242	6.90	

[1] From Xiao (1988)

[2] From Tumwasorn (1981) - see previous page.

Konanta et al. (1984) compared the working ability of 16 Murrah crossbred with 16 swamp buffaloes being supplemented or not with 1.5 kg/d a 3:1 mixture of cassava chips and ipil-ipil leaf meal. It was demonstrated that the swamp buffaloes had a higher work ability in terms of being able to plough more land per unit of time but at a similar speed when compared to the crossbred. In addition, the groups that were fed the supplementary diet could plough at a significantly higher speed and gained more weight than the non-supplemented ones.

Not many studies on feeding and management of buffaloes for milk production have been conducted. Dairy farmers in the region generally take the conventional feeding system, good quality forages with concentrate feeds supplementation, for granted and the available resources may not always be used at their maximum economic efficiency. Taking into account the limited availability of good quality forages under small farm conditions, the low producing milking buffaloes of the multi-purpose crossbreds may have to produce on crop residue-based feeds. An alternative approach, enabling a more efficient utilization of such feeds, has to be formulated, tried out and implemented.

One of the alternative approaches to achieve a better utilization of fibrous crop residues as feeds for milking buffaloes is pre-treatment prior to feeding. A number of studies have been done, in South Asian countries, on evaluating the feeding value of urea-treated rice straw for dairy buffaloes.

Positive responses have been reported by Khan and Davis (1981) and Perdok et al. (1982 and

1984) (Table 4). Once such pre-treatment has proved socio-economically acceptable to small farmers, much benefit can be gained. This remains to be proven.

Table 4. The performance of Surti buffaloes given untreated or urea-treated straw-based diets, with concentrates and with or without Glyricidia leaves.

	UTS+C	UTS+G+C	TS+C	TS+G+C
Milk yield (kg/d)	2.17	2.56	2.97	3.35
Milk fat (g/d)	146	178	224	256
Milk fat (%)	6.71	6.94	7.54	7.62
Cows in milk after 10 wks	6	9	10	9
Wt gain of calves(g/d)	165	265	295	344
Wt change of cows (g/d)	-93	+59	+59	+126
DM intake (g/kg $W^{0.75}$)	119	123	163	178

UTS = untreated straw;
TS=Treated straw;
+C= + 1 kg concentrates/d
+G = + 6 kg Glyricidia leaves per day

From Perdok et al. (1982)

Supplementation of crop residue-based feeds with a more nutritious locally available by-products is another alternative for better utilization of the available feed resources in the small farm system. Preston (1986) and Preston and Sansoucy (1987) formulated a method of strategic supplementation in the feeding system by taking into account the ecological manipulation of rumen microbes so that the maximum digestion of dietary fibre can be

achieved. In addition, supplementation of the by-pass nutrients required to correct the major constraints of milk production has been included in their recommendation. With respect to management, "restricted suckling" of the dual-purpose cow by her calf, enabling both calf growth and milk production to benefit, has been recommended. This appears to fit well with the small farm situation and remains to be tried out on South-east Asian small farms.

RECOMMENDATIONS FOR FUTURE RESEARCH AND DEVELOPMENT

In order to maximise the production potential of swamp buffaloes in South-east Asian small farms, work on crossbreeding with the dairy breeds is needed. Well-planned breeding programmes, aiming to produce multi-purpose crossbreds, should be done in order to make full use of the animals which are normally engaged in crop cultivation for only 130 days a year. Performance testing of the crossbreds needs to be undertaken on farms in order to simultaneously assess their suitability under the socio-economic setups of the small farmers.

A village survey which aims to assess basic data on the acceptance by small farmers of changing the pattern of raising the draught to multi-purpose buffaloes in their systems is greatly needed. Reorientation of their attitudes toward making use of their female buffaloes for both work and milk should be advocated.

On feeding and management, work on the assessment of crop residues and farm by-products available as feeds should be initially evaluated. The improvement of their utilization whether by means of pre-treatment and/or supplementation should be investigated and further tested on farms in order to formulate practicable and acceptable recommendations, enabling a sustainable milk production system based on the small farmers' available resources. A comparative study on the conventional rearing and restricted suckling of calves should be conducted in order to assess the economic gains, taking into account the improvement in both

calf growth and milk yield.

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FUTURE PROSPECTS FOR FODDER AND PASTURE PRODUCTION

By

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INTRODUCTION

In the wet tropical environment, there is no distinct seasonal moisture deficiency and the foliage is green throughout the year. The potential production of tropical forage both native and improved species, in terms of protein, metabolisable energy and milk production, has been favourably assessed (Lane and Mustapha, 1983; Luxton, 1983).

The tropical dairy breed, which is basically a Bos indicus animal, has a low potential for milk production which is between 500–950 kg/lactation (Samuel, 1974; Sivarajasingam, 1974), whereas the milk production potential of the crossbred (Bos taurus × Bos indicus) is improved, giving 1,200–1,900 kg/lactation (Sivasupramaniam and Nik Mahmood 1981). Due to the overall feed constraint and environmental stress, purebred dairy cows such as Friesian and Jersey are merely able to produce half of their milking potential (1,150–2,200 kg/lactation) (Wan Hassan et al., 1981; Sivasupramaniam and Nik Mahmood, 1981), compared to those of similar breeds in a drier environment. The expected milk yield is estimated to be 2,700–4,000 kg/lactation for the Friesian and Jersey (Cowan et al., 1975). Hence, the genetic expression of milk production of the dairy cow is confounded by tropical environments.

This paper attempts to present the status, constraints, potential production and management of tropical forages in relation to the feeding of dairy cattle inthe tropics.

NUTRITIONAL VALUE OF TROPICAL PASTURES

It is commonly believed that the contribution in milk production due to genetic factors of animal is about 25%. A greater sustainability of production is produced by better feeding. Pasture can be a major source of feed for dairy cows but there are some limitations to its use. Energy and protein supplies are the most essential components in animal nutrition and, in many tropical countries, these components are often the critical limiting factors to animal production.

Most of the tropical grasses (either native or improved pastures) have metabolisable energy values ranging from 7.0 to 11.0 MJ/kg DM when cut between 2–8 weeks (Table 1), and energy concentrations for natural forages were found to be similar (7.1 to 10.1 MJ ME/kg DM). Lane and Mustapha (1983) also reported that broadleaved species and ferns appeared to have higher metabolisable energy values and their crude protein and crude fibre was superior to natural grasses. Based solely on the metabolisable energy available from the existing forage on offer, Lane and Mustapha (1983) estimated the potential milk production of Friesian-Sahiwal cows in mid-lactation to be 12–16 kg/cow/day depending upon the types of pastures.

Table 1. Mean chemical composition and estimated ME value of some improved tropical pastures (Wan Hassan, 1987)

Grass/Cutting Interval (week)	in vitro DMD %	CP	CF	Ash	Estimated ME (MJ/kg DM)*
		g/kg DM			
Setaria					
2	66.00	189.86	256.69	99.61	9.18
4	60.29	143.17	286.17	98.58	8.42
6	56.09	121.95	314.42	86.38	7.96
8	53.09	104.71	329.27	77.67	7.62
Digitaria					
2	64.24	158.37	273.97	95.77	8.98
4	59.06	139.64	301.79	81.83	8.41
6	55.32	100.89	319.74	79.29	7.92
8	51.90	88.14	334.47	67.80	7.54
Napier					

2	65.60	178.08	256.54	115.55	8.97
4	59.35	124.31	301.65	95.55	8.32
6	54.60	100.00	330.58	91.00	7.71
8	50.92	70.15	343.20	73.33	7.36
Guinea					
2	64.04	172.87	279.34	111.23	8.80
4	57.69	127.27	324.10	88.17	8.16
6	53.88	91.05	350.90	80.63	7.71
8	49.89	62.57	367.36	69.83	7.24
Signal					
2	63.52	154.92	269.66	97.76	8.96
4	57.66	119.29	300.10	81.00	8.22
6	55.03	92.58	325.61	77.86	7.89
8	53.56	76.00	345.73	68.73	7.76

*** ME (MJ/kg DM) = 0.15 (DMD%+2% units) (100-Ash%)÷100**

Protein content varies with age, part of the plant and species. Most of the tropical pastures have crude protein contents ranging from 7 to 12% for grasses and more for legumes like Leucaena, which has 25% protein content. Protein content of tropical pastures decreases rapidly as growth progresses.

As a general guide, 10% crude protein on a dry matter basis is adequate for fattening cattle but about 15% crude protein or more is required for high producing milking cows. The critical level of crude protein required in the pasture before intake is reduced by a protein deficiency has been estimated at between 6.0 and 8.5% (Milford and Minson, 1966; Minson, 1967). The

deficiency of crude protein in pasture can be corrected by the use of tropical legumes or nitrogen fertiliser on pure grass pastures.

The digestibility of cultivated tropical grasses lies between 50 and 65%, whereas temperate grasses range from 65 to 80% (De Gues, 1977). Thus it is necessary to utilise immature herbage in order to obtain a high metabolisable energy intake. Milford and Minson (1966) showed that the decline in digestibility with age was more rapid in tropical grasses compared with tropical legumes, which retained relatively high digestibilities at maturity. Values recorded for a number of different tropical grasses indicate that there is a decrease of 0.1 to 0.2 digestibility units/day with increasing maturity (Minson, 1971). This explains why tropical legumes are particularly valuable for animals in the dry season.

PASTURE SPECIES SELECTION AND PRODUCTION

Species Performance and Adaptation

Selection of pasture species should take into account the nutritional requirements of different classes of livestock, as well as the suitability of the plant for different animal production systems such as large scale or smallholder production.

Lately, improved species which had gone through the screening process in the wet tropics are the following genera:

Grass: Brachiaria, Digitaria, Panicum, Setaria and Pennisetum

Legume: Centrosema pubescens, Desmodium ovalifolium, Pueraria phaseoloides and Leucaena leucocephala (Wong et al., 1982).

The performance of the above mentioned species evaluated under different soil types are listed in Table 2. In general, on sedentary soil and peat soil, dry matter production ranged from 15.0 to 30.0 ton/ha/yr, whereas the same species grown on coastal marine sand dropped to almost a third or a half of their normal yields.

Table 2. Dry matter yield (ton/ha) of grasses and legumes under cutting in three regions in Malaysia

Species	**Sedentary soil**	**Peat soil**	**Sandy soil**
Grasses:			
Brachiaria decumbens	24.7	26.3	16.5
Brachiaria brizantha	19.4	24.5	11.8
Digitaria secivalva	20.5	25.4	3.8
Digitaria pentzii (Slenderstem)	18.2	23.1	11.8
Panicum maximum (Coloniao)	17.0	20.2	3.1
Panicum maximum (Typica)	26.1	-	-
Setaria sphacelata (Kazungula)	20.6	15.8	6.7
Setaria sphacelata (Splendida)	18.6	16.6	-
Pennisetum purpuruem	30.0	16.3	3.4
Legumes:			
Centrosema pubescens	6.0–10.0	5.0–8.0	3.0
Desmodium ovalifolium	5.0–7.0	7.0–9.0	3.0
Stylosanthes quianensis (Schofield)	7.0–15.0	5.0–7.0	7.0–10.0
Leucaena leucocephala	8.0–20.0	10.0–15.0	5.0–6.0

Adapted from Wong et al., (1982).

Fertiliser applied at 300–400 kg N/ha/yr; cutting interval of 4–6 weekly.

The grass species Napier, and to certain extent Guinea, are mostly used for cutting while the rest are meant for grazing. In view of the grass-legume combining ability, it is proposed that the grasses with erect and clumpy characteristics such as Panicum maximum, Setaria sphacelata can combine well with all the promising tropical legumes, especially Desmodium ovalifolium and Centrosema pubescens, which need a shady canopy. Sometimes, legume species which are not that palatable, such as Calopogonium caerulum, C. mucunoides and S. scabra, may have to be included in the pasture system so as to serve specific objectives such as preservation of feed for drought and nitrogen fixation for soil improvement. Care is required with aggressive grasses with prostrate rhizomes which form a thick mat on the ground surface which may impede the legume. Selection of shrubby legumes for this system could be probably the best way out, for instance, the L. leucocephala and B. decumbens pastures.

Cutting and grazing

It is important to note that for most grasses and legumes, forage yield increases as cutting frequency decreases while forage quality declines. The digestibility of both grasses and legumes decreases with maturity, implying that forage should be fed at a younger stage for maximum energy digestibility. A wide range of digestibility occurs both between and within pasture species. One has to compromise between maximising forage yield and quality and try to improve the latter by using better species for milk production.

In general, defoliation affects the both above ground growth and the underground rooting system. In the case of legumes, it affects also nodulation and nitrogenase activity. When sufficient fertilizer and moisture are available, a 6 to 10 weeks regrowth interval should be the practice to obtain optimal yield and quality of forage, except in the dry season, when the

cutting interval may inevitably be prolonged.

In the case of grazed pastures with defoliation by dairy cows, either by continuous or rotational grazing, the optimal leaf to stem ratio should be maintained at close to 1, giving forage availability of about 2500 kg/ha of dry matter at any time (Cowan et al. , 1977)

Response to Fertiliser

In tropical regions, where light and moisture are non-limiting, soil nutrients are the major factors affecting the production of forage. Due to highly weathered soil conditions, deficiencies of macro- and micro-nutrients in ultisol, oxisol, peat and marine sand were reported (coulter 1972; Chew et al., 1981; Tham and Kerridge 1979, 1982). Nutrient deficiencies may lead to the non-persistence of the species, especially with legumes which are sensitive to molybdenum, copper, magnesium, boron and calcium. They may eventually affect animal production, e. g. cobalt deficiency both in soil and pasture (Mannnetje et al., 1976b). There is a response of pasture growth and animal performance to the application of phosphorus fertilizer (Eng et al). , 1978).

A high rate of nitrogen fertilizer is necessary to maintain high productivity of fodder grasses. The dry matter yields of some of the improved and native species in response to nitrogen fertilizer are documented (Ng, 1972, Vincente-Chandler et al., 1959. Dry matter yield responses have been recorded up to as high as 1,600 kg N/ha/yr (Tham, 1980). Even though high rates of nitrogen increase dry matter yield, the efficiency of use of nitrogen was found to decrease with increase rates of nitrogen applied. The nitrogen efficiency drops from 23.0 to 20.1 to 17.6 to 16.8 kg DM/kg N as nitrogen rate increases from 200 to 400 to 600 to 800 kg N/ha/yr respectively. Whereas at the same rate of application, the nitrogen recoveries were 30.3, 38.4, 41.9 and 42.7% (Chadhokar, 1978).

Similar results on napier and signal grass were recorded at rates of 42.0, 34.2 and 25.2% nitrogen recovery as the nitrogen application rate increases from 200–400, 400–800 and 800–1600 kg N/ha/yr (Tham, 1980; Aminah et al., 1989). It implies that the most efficient nitrogen fertilizer rate should be around the level of 200–400 kg N/ha/yr. This further confirmed an earlier finding that nitrogen concentration in the forage had a limited effect on increasing the nutritional value (Minson 1973) and that nitrogen fertilizer at 250 kg N/ha/yr was sufficient for the attainment of crude protein for optimum digestion by the animal in the wet tropics (Mustapha et al. , 1987). Furthermore, excessive crude protein in tropical grasses following heavy application of fertilizer nitrogen may also adversely affect intake. Milford (1960) recorded a depression of 33% in the intake of Chloris gayana when crude protein content increased from 8 to 13.5% due to high nitrogen fertilizer application. A similar case was reported that the intake of young, heavily fertilised pasture with 20% crude protein was 28% less than the intake for the same pasture after growing for a further 28 days when the crude protein had fallen to 11%

There are interaction of N, P and K fertilizers on forage production. With application of N, P and K fertilizer at the rates of 421, 196 and 1004 kg/ha/yr respectively, the yield of fresh napier grass increased by 74.5% over the yield of unfertilised grass. It is recommended for a broad range of soils in the humid tropics that fertilizer rates of 300–600 kg N, 100 kg P and 50 kg K/ha/yr should be sufficient for forage production under cut and carry system (Robbins, 1986). Based on research work and experience on grazed pastures, Gilbert (1984) has attempted to recommend fertilizer for different soils derived from granitic, metamorphic, basaltic and marine sand (Table 3).

Table 3. The fertilizer rates for grazed pastures on different soil types (Gilbert, 1984).

Fertilizer	Granitic soil	Metamorphic soil	Basaltic salts	Marine sand
Superphosphate	300 kg/2yrs	300 kg/2yrs	300 kg/yr	150 kg/yr
Muriate of Potash	100 kg/4–5yr	100 kg/4–5yr	-	50 kg/yr

Copper sulphate	8 kg/4 yr	-	-	8 kg/4yr
Zinc sulphate	8 kg/4yr	-	-	8 kg/4yr
Sodium molybdate	0.5 kg/4yr	0.5 kg/4yr	0.5 kg/2yr	0.5 kg/4yr
Lime	-	500 kg/ha	-	-

On a pure grass sward grazed by dairy cattle, it is advisable to split the amount of 300 kg N/ha/yr of nitrogen fertilizer into five equal applications. The economic aspects of fertilizer use has to be assessed in relation to the increased dry matter yield and its subsequent effect on animal carrying capacity.

Legume in the Pasture

To maintain high productivity and forage quality for dairy cows, it may be better to include leguminous species in the pasture production system rather than rely on nitrogen fertilizer. The advantages of legumes in the system are:

i. **improvement of soil conditions due to nitrogen built up in the soil from accumulation of organic matter,**
ii. **fixation of nitrogen by the legume through Rhizobium symbiosis, and**
iii. **increased animal production due to the higher nutritive value of legumes and shorter digestive passage time in the gut that enhance voluntary intake.**

Usually, the crude protein content of legumes (at about 25%) is higher than that of grasses at similar ages and stages of growth and shows little fluctuation during the growing process. Apart from higher nitrogen content, tropical legumes generally maintain higher sulphur (0.07–0.21%) and calcium (1.13–1.93%) in the plant tops (Andrew and Robbins, 1969) as compared to

that of grasses (0.09–0.15% and 0.17–0.41%, respectively). Similarly, the values of phosphorus in legumes are expected to be higher than grasses despite great variability between species and plant age. The additional role of legumes in increasing the mineral content of pastures has an additive effect on animal nutrition and production.

Legume viability and persistence on acidic soil are always problematic. The inclusion of local legumes or well-adapted species as one of the leguminous components in the pasture is highly recommended. Becauseof specific requirements for certain elements for nitrogen fixation, the legume may be more sensitive to some minerals such as phosphorus, sulphur, calcium, magnesium, molybdenum and cobalt.

There are many factors affecting legume component in the tropical pastures. The most important but controllable factors are the defoliation, grazing management and fertilizer. Very little is known about the optimum level of legume content in the tropical pasture. Results from grazing pangola-legume pasture have shown that the live weight gain of beef cattle was linearly related to legume content of the pasture (Evans, 1970).

PASTURE MANAGEMENT AND MILK PRODUCTION

Average production per cow from tropical pastures is in the range of 10 to 12 kg/day for Friesian cows, 7 to 9 kg/day for Jersey and 6 to 10 kg/day for crossbred cattle. The potential of these pastures for milk production was suggested to be 4,000 kg/lactation for Friesian and 2,700 kg for Jersey (Cowan et al., 1974). Production per hectare varies from 2,600 to 8,300 kg/ha/yr. Grass and legume systems have produced up to 8,000 kg/ha/yr, but these stocking rates caused degradation of the pasture due to loss of legume (Cowan et al. , 1975). A production level of 5,000 kg/ha/yr is the potential of stable grass and legume mixed pastures. (c)

Continuous Grazing

Cows grazing tropical pastures require about 10 to 12 hours a day of grazing to satisfy their nutritional needs (Cowan, 1975). Often they are reluctant to do a lot of grazing during the day as the temperature are high. In Northern Queensland during summer, about 80% of grazing are done during the night. Obviously, night grazing or feeding in the tropical environment, must be encouraged.

There is linear increase in milk output per hectare with increase in stocking rates but milk production per cow also decreases linearly (Cowan, 1984). There are a wide range of stocking rates tested for milking cows on different types of pastures (Table 4). The optimal stocking rate for Friesian milking cows on Guinea-Glycine mixed pasture was 1.6 cows/ha to produce 5,351 kg/ha/yr (or 3,345 kg/cow/yr) of milk, whereas on nitrogen fertilised Guinea was 3.5 cows/ha to produce 8,880 kg/ha/yr milk yield. Both stocking rates were able to maintain stable pasture of about 2,500 kg DM/ha on offer, the amount of forage considered to be minimum for dairy production.

For practical purposes, when advising a farmer on the basis of experimental results, it is best to be conservative at 20–30% lower stocking rates than those used in the research.

Rotational Grazing

On reviewing over 16 grazing experiments, Mannetje et al. , (1976a) concluded that there is no definite advantage of rotational grazing over continuous grazing system. However, in the hot humid tropics where even rainfall is available, the rotational grazing system has a 25% higher in beef production than that of the continuous (Chen and Othman, 1986). This is attributed to a higher amount of forage on offer rather than forage quality in the rotational grazing system.

The practice of rotational grazing (or strip grazing) may help to ease the forage problem, particularly during a prolonged dry spell.

Table 5. Milk production from N-fertilised and legume-based tropical pastures without supplementary feed

Pasture	Stocking Rate	Breed	Milk yield		References
			kg/cow/day	kg/ha/yr	
Unfertilised pastures					
P. maximum/M. minutiflora	1.1	Jersey	6.8	2667	Toledo 1968
D. decumbens	1.5	Friesian/Zebu	6.9	3760*	Serpa et al.,1973
Nitrogen fertilized pastures					
D. decumbens	2.5	Jersey	6.8	6014	Toledo 1973
D. decumbens					
(irrigated)	8.9	Jersey	6.5	22466	Thurbon et al., 1973
P. maximum	2.5	Holstein	11.3	8488	Vincente-Chandler et al. , 1974
Grass-legume pastures					
B. decumbens/Leucaena	5.0	Sahiwal-Friesian	5.7	8580	Wong et al. ,1987
P. maximum/Glycine	2.5	Friesian	12.7	8221	Cowan et al.,1975

*** Calculated yield**

Cut and Carry System

The "cut and carry" (or zero grazing) system means that the fodder is cut and removed for stall-feeding to animals. This system has been widely adopted by smallholders in dairy farming. The reasons for this practice are the shortage of land, small scale of farm size (0.3–2.0 ha), abundance of cheap labour, limited forage resources and strict control of animals.

Usually, when cut forage is given, the nutritive value of forage is inferior to that received by grazing animals. The protein content of napier grass by cattle was 17.1%, while that of the same forage being fed to stall kept animal was 7.4% (Vincente-Chandler et al., 1964). Grazing animals are able to choose their own forages. Grazing cows tend to produce more milk and obtain better reproductive performance than stall-fed cows. Milk production in the stall-feeding system was 8,577 kg/ha/lactation while rotational grazing without supplements yielded 9,180 kg/ha (Wong et al., 1987). A similar finding was obtained with 20% higher milk production for grazed cows (10,203 kg/ha/yr) than that of stall-fed cows (8,134 kg/kg/yr) (Soetrisno et al., 1985). This may explain the low milk yield of the smallholders.

Like grazing animals, stall-fed milking cows need night feeding. In order to have a near-balanced diet, some broadleaved weeds such as (Asystasia intrusa and others) or leguminous shrubs (such as Leucaena and Glyricidia species) in place of a high protein supplement, should be included. Protein is an expensive supplement at smallholder level.

Frequent defoliation of herbage is a threat to the persistence of sward and it may result in the need to replant the pasture. If it is a machine-cut, the mortality of forage plants will be higher than handcut materials. Experience shows that Napier grass cut by forage harvester has to be replanted every three years. The severity of forage die-back may be reduced if a reciprocal cutting machine is used.

Replenishment of soil fertility is essential with the cut and carry system. It was estimated that

to be able to produce 150 t/ha/yr of fresh Napier/Guinea fodder, a fertilizer programme of 880 kg N, 252 kg P and 756 kh K/ha/yr (or 6.3 ton of 14:14:12 compound fertilizer) is needed. On the highly-leached acidic soils of the tropics, "soil exhaustion" may be experienced, despite the frequent application of N, P, K fertilizers. The consequence is the rapid die-back or retarded growth of forage sward. It may be due to the following factors:

i. **high hydrogen ion concentration (urea source),**
ii. **toxic level of aluminium and manganese, or**
iii. **induced deficiency of molybdenum.**

Correction of such a problem probably requires the incorporation of organic matter or animal waste into the soil, as well as the application of recommended fertilizers. Organic matter which is the source of much nitrogen, and to a certain extent phosphorus and sulphur, improves soil condition. Organic matter improves also the inorganic particles (the clay colloids) which are the main reservoir of cationic nutrients such as K, Ca, mg, Fe, Zn, Mn and Co.

Some micro-elements which are not essential to plant growth such as sodium and cobalt are critical to animal performance. Even the major nutrients such as phosphorus, potassium, calcium and nitrogen if they are low in fodder plants, will affect milk production. Supplementation of minerals to animal to correct the immediate need must be given.

<u>Forage-based Supplementary Feeding</u>

In areas where dairy cattle are kept near a pineapple factory, palm oil mill, sugar-cane plantation or in any major agriculture operation from which crop by-products are plentiful, a complete year round feeding system involving these by-products could be established. By-products do not provide a balanced feed on their own, being either excessive or deficient in

certain minerals, but they are good roughage with high metabolisable energy. They may be available or harvested only in a certain period of the year, mostly approaching the dry season when shortage of green forage is experienced.

Besides the agriculture by-products, the conservation of feed in the form of silage or hay may be another alternative to ease the situation of feed shortage on the farm. Due to low leaf:stem ration or high fibre content, tropical pasture may not be that good for silage and hay making, but with some additional mixing with leguminous shrubs, good quality feed can still be maintained. Hence, using forage as a basic diet, supplementary feeding of formulated by-products in the ration, may possible be able to maintain full milk production throughout the year.

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FORAGE AND LEGUMES AS PROTEIN SUPPLEMENTS FOR PASTURE BASED SYSTEMS

by

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INTRODUCTION

Major emphasis for pasture improvement in the tropics has been placed on grass-legume pastures. The grass-legume approach in pasture development is based on the knowledge that tropical soils often lack nitrogen and on the general philosophy that the legume-Rhizobium

symbiosis can provide a more economical source of N. The ability of legumes to fix nitrogen from the atmosphere, in association with the Rhizobium bacteria, gives the plants a dual-role of providing an improved diet to growing animals and of increasing soil fertility through release of nitrogen.

Legumes provide high-quality protein and energy, often critical during the dry season when animals, feeding solely on grass, lose much of the weight they gained during the wet season. Pasture scientists in the tropics had shown the potential and value of grass-legume pasture and an increasing number of cattle raisers are appreciating it.

CHARACTERISTICS OF TROPICAL PASTURES

Most of the native pastures in the tropics are dominated by grasses like Imperata, Themeda, Chrysopogon and Aristida which have a short growing period or mature very quickly compared to the temperate pasture species. Protein deficiency is very common in tropical grasses, particularly the native species (Humphreys, 1972). Crude protein of native pastures is usually below 3%, particularly during the dry season and, when crude protein levels fall below 7 to 8%, animal production would be limited by protein deficiency (Evans, 1968). In addition, most of the grasslands in the tropics are found in marginal areas with low fertility status and are invaded by non-palatable species which dominate the area with increasing grazing pressure.

The value of legumes in pasture

The nutritive value and digestibility of tropical legumes is higher than that of tropical grasses and the quality of herbage from grasses rapidly declines with increasing maturity. In contrast, herbage from the legumes remains good throughout the growing period, except for the fodder trees which become woody as they mature, although such a situation is easily overcome by

regular lopping of the plants.

In addition most of the tropical legumes are more productive than the grasses during the dry season, making them more valuable as sources of additional high quality feed during this period, thus increasing the year-round carrying capacity of pasture.

Legumes in native pasture

A number of studies showing the value of tropical legumes to grazing animals has been done in Australia and recently several results have been reported from numerous grazing trials conducted in Thailand, Malaysia and the Philippines, with most of the studies done on liveweight gain of beef cattle. Most of the studies however are on beef production from legume-based pastures involving Centrosema (Centrosema pubescens), Townsville Stylo (Stylosanthese humilis), Siratro (Macroptilim atropurpureum), Schofield and Cook Stylo (S. guianensi), Seca Stylo (S. scatia),, Verpuo Stylo (S. hamata) and Ipil-ipil (Leucaena leucocephala).

Table 1 shows the summary of liveweight gain data obtained from various studies in the Philippines. The data indicated that animal production from native pastures can be increased two- to four-fold by incorporating suitable pasture legumes, particularly with the Stylos which thrive well in dry acidic conditions. In Mabate, Imperata pastures overseeded with Centro or Stylo can easily support 1 animal unit per hectare with more or less 100 kg liveweight gain per hectare per year, while pure Imperata pasture stocked at 0.5 and 1.0 animal unit per hectare produced only 22 to 25 kg LWG per year, coupled with the animal loss in weight during the dry season.

Table 2 shows beef production on improved grass/legume pastures in the Philippines.

Napier/Centro pasture fertilized with 65–45–45 NPK produced 128–148 tons of fresh herbage per year in a study conducted at ANSA farms. This pasture safely carried three animals per hectare with beef production of 475 kg liveweight gain per hectare per year. With four animals, the pasture had 806 kg liveweight gain per hectare but ran out of grass for 37 days and corn-stover supplementation was carried out.

Cowan (1986) summarised the levels of milk production that have been obtained from tropical pastures in Table 3. The grass and legume mixed pastures gave higher production per cow than nitrogen fertilized grass pastures. However, they cannot carry as heavy stocking rates as nitrogen fertilized grass and production per hectare is lower. Average production per cow is of the order of 10 to 12 kg/day for Friesian cows, 7 to 9 kg/day for Jersey and 6 to 10 kg/day for crossbred cattle. Production per hectare varies from 2, 600 to 8, 300 kg/year. Grass and legume systems have produced up to 8,000 kg/ha/yr, but loss of legume was observed at high stocking rates (Cowan et al., 1975)

Table 1. Live weight gains on Imperata and Imperata/legume pasture.

Location/animal	**Pasture**	**Stocking rate (a.u./ha)**	**ADG (kg)**	**LWG/hd (kg)**	**LWG/ha (kg)**
Masbate (cattle)	**Imperata**	0.5	0.12	43.2	21.6
	Imperata	1.0	0.07	26.6	26.6
	Imperata/Stylo	1.0	0.32	116.6	116.6
	Imperata/Centro	1.0	0.25	91.8	91.8
Bukidnon (cattle)	**Imperata**	1.0	0.21	77.4	77.4
	Imperata/Centro	1.0	0.26	94.1	94.1
	Imperata-Themeda	0.5	0.24	85.4	42.7

Bohol (Carabao)	**Imperata-Themeda**	1.0	0.22	78.9	78.9
	Imperata-Themeda/Stylo	0.5	0.35	127.0	63.0
	Imperata-Themeda/Stylo	1.0	0.25	92.2	92.2
Bohol (Carabao)	**Imperata**	0.75	0.22	68.1	51.1
	Imperata/Leucaena	1.5	0.35	111.9	167.9
	Imperata/Leucaena	2.0	0.28	87.4	174.8

Table 2. Liveweight gain production on improved grass/legume pastures.

Location	**Pasture**	**Fertilizer rate (kg/ha/yr N-P-K)**	**Stocking rate (au/ha)**	**ADG kg**	**LWG/hd kg**	**LWG/ha kg**
Bukidnon	**Para grass/Centro**	0–50–0	2.0	0.423	155.9	311.8
	Para grass/Centro	0–50–0	2.0	0.419	150.9	305.8
ANSA Farm (South Cotabato)	**Napier/Centro**	65–45–45	2.0	0.428	156.5	313.0
	Napier/Centro	65–45–45	3.0	0.431	158.0	474.0
Bohol	**Guinea/Cook Stylo**	24–24–24	2.0	0.240	86.4	172.8
	Guinea/Cook Stylo	24–24–24	2.5	0.280	100.8	252.0

	Guinea/Cook Stylo	24–24–24	3.0	0.220	79.2	237.6

Table 3. A Summary of milk production per cow and per hectare from cows grazing tropical pastures.

	Breed	**Stocking rate (cows/ha)**	**Milk yield (kg/cow/day)**	**Milk yield (kg/ha/yr)**
Unimproved pastures	**Jersey**	1.1	6.8	2660
	Guernsey	1.5	6.9	2670
	Jersey/Criollo	1.0	6.9	2660
	Friesian/Zebu	1.5	6.9	2760
Improved grass-legume pastures	**Jersey**	1.0	8.5	-
	Guernsey	1.8	9.3	4700
	Friesian	1.6	12.4	5350
	Friesian/Zebu	1.7	7.3	3720
	A.F.S.	1.6	8.0	3840
Improved nitrogen fertilized pastures	**Jersey**	2.5	6.8	5250
	Guernsey	2.5	7.8	5350
	Friesian	2.5	11.0	8250
	Friesian/Zebu	2.2	8.7	5200
	Jersey/Criollo	2.6	6.7	4100
	A.F.S.	2.5	7.0	4800

TREE LEGUMES

Shrub and tree legumes are a good source of protein and have been gaining importance for livestock production in S.E. Asia and other tropical countries. Fodder tree legumes have several attributes that make their potential use in the tropics very high. The legumes have deep root system and can withstand drought and often serve as the main source of forage during the dry season. Some of the tree legumes are multiple purpose plants and are often grown for fuel wood, timber poles and even a source of food, in addition to fodder. Tree legumes, once established, are easier to maintain in association with tropical grass compared to conventional creeping legumes and they can be grown as an upper story on land used for growing crops at lower levels. Some of the legumes with known use and potential as a source of fodder are species belonging to the genera of Albizzia, Callandra, Gliricidia, Mimosa, Leucaena, Samanea and Acacia. Among the legumes, Leucaena leucocephela is most well studied while the value of Gliricidia maculata is now being recognised, along with other species as a source of fodder.

In the Philippines, Ipil-ipil or Leucaena is the most popular legume and has been given a great deal of attention since the early seventies, with people in the livestock sector looking at it almost on a 'cure-all' for the growing animal industry. This bias worked against the sector because, in 1985, Leucaena was infested by a 'jumping lice' or psyllid (Heteropsylla cubana) and we were not prepared with an alternative species. Currently, the infestation is still around but not as destructive as in 1985–1987 when the intensive cattle-fattening, smallholder farms were badly affected, forcing them to reduce animal holdings or stopped operations.

The infestation also affected the feed milling industry which utilized Leucaena as a source of xanthophyll and carotene in mixed feeds. Likewise, it also affected the smallholder farmer who grew, harvested and sold the leaves to the feed merchants and feedmills.

Smallholder dairy farmers raising Sahiwal-Holstein Friesian feed their animals with 5 to 19 kg fresh Ipil-ipil leaves in combination with fresh grass fodder and obtain 4 to 7 kg milk per cow

per day. Ipil-ipil is planted in hedges around the home-lots and farmlots, and in evenly spaced rows (1m to 2m) under coconuts.

Liyanage and Jayasundera (1988) reported that several trials conducted by the Coconut Research Institute in Sri-Lanka have demonstrated the value of Gliricidia as an animal feed. Gliricidia loppings mixed with Brachiaria milliformis in 50-50 ratio and fed to crossbred heifers resulted in an average live weight gain of 700 g/head/day. In another trial, a mixture of Gliricidia and Leucaena was planted alternately 1.5 m apart along the fence in a pasture/ cattle/coconut integrated system and produced more than 2 MT/ha/year of fresh green matter. This, when fed to heifers at the rate of 6 kg along with a pasture during the dry season, produced average live weigh gains of 300 g/head/day. Freshly chopped Gliricidia leaves can also reduce the duration of urea-treated straw from 21 to less than 6 days.

Gliricidia leaves are succulent but may not be very palatable to animals when first introduced. However, livestock freely eat when they become accustomed to the taste. Table 4 shows that Gliricidia, when fed with Siguaue (Brachiaria brizantha) grass from 0 to 100% for one month to Jersey milch cows, had no adverse effect on their health or milk production and was very palatable (Chadhokar and Lecamwasam, 1982). However, tainting of milk when Gliricidia is fed above 50% supplementation level has been reported but this may be avoided if feeding of this material is stopped a few hours before milking.

Table 4. Effect of Gliricidia maculata in a mixture with Brachiaria brizantha on milk yield and its composition

Treatment	Average Milk Yield (litres/cow/day)		Average Milk Composition (Percentage)		
Percentage Gliricidia	Pre-exptl.	Exptl.	Fat		Solids not-fat
			Pre-exptl.	Exptl.	
0	5.5	5.8	4.8	4.7	8.3

25	5.2	5.8	5.2	5.1	8.6
50	6.5	5.7	5.7	5.8	8.8
75	3.8	4.6	5.1	5.3	8.4
100	6.7	7.6	5.3	5.8	8.6

SUMMARY AND CONCLUSIONS

Vine and tree legumes are very valuable components in livestock feeding systems in the tropics. Increasing population trends indicate that more of the grassland areas will be diverted to crop production and will limit the use of pasture legumes to marginal areas where crop production is economically less or not feasible. Smallholder livestock production will increase in proportion and fodder trees will be socially and economically viable.

Livestock research and development programmes should focus on utilisation of tree legumes relevent to existing farming systems in smallholder farms in the tropics.

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