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Review Article

Prioritizing Improvements to Traditional Management Practices on Small Holder Dairy Farms in the Humid Tropics of Asia

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ABSTRACT

Throughout the humid tropics of Asia, small holder dairy (SHD) farmers have developed their production systems largely based on the "traditional way of doing things". Tradition is a generic word used in this case to mean basing farm management decisions and practices on how their father, or friends or even next door neighbours do things. The low levels of milk production and herd fertility, the high incidences of calf mortalities and poor animal health (such as lameness and mastitis) and the inferior quality of much of the milk sourced from these farms are clear indications that many of these traditional farm management practices are in urgent need of re-evaluation.

Many of problems arise because of poor cow comfort and feeding management. Farmers do not give enough attention to cow comfort. Excluding feed quality factors, depressed appetite is largely the result of poor farm management practices. In addition, the majority of SHD farms have too many underfed stock. Maintaining fewer cows and using feed resources to better feed the remaining should be one of the major objectives of small holder dairy farming.

This review discusses many of these routine farm decisions and practices in the light of how they could and should be modified to improve their outcomes. These are categorised into two topics, firstly, improving the time management on the farm and secondly, investing in improved farm management. Many changes in management practices have negligible costs apart from spending more time on any one task. All too often farmers are just reluctant to spend money on improving farm facilities, equipment and consumable items. This review has prioritised these improved practices. It is now up to the many dairy stakeholders in Asia's humid tropics to disseminate them throughout their dairy industries.

Key words: Humid tropics, small holder dairy farming, improved management practices

INTRODUCTION

Throughout the humid tropics of Asia, small holder dairy (SHD) farmers have developed their production systems largely based on the "traditional way of doing things". Tradition is a generic word used in this case to mean basing farm management decisions and practices on how their father, or friends or even next door neighbours do things. This is complementary with their own trial and error experiences and maybe some advice from service providers, such as dairy cooperative, government advisers or milk supply officers from commercial dairy processors. Rarely do SHD farmers take full advantage of all the information sources available to them, with many of them available for free.

With the rapid increases in knowledge related to herd and feeding management of milking cows, particularly animal welfare and cow comfort, traditions soon becomes outdated. However unlike dairy farmers in developed countries, those in the developing dairy industries do not seem to be as exposed to the latest information or if exposed, do not seem sufficiently receptive to adopt many of the resultant improved farm practices. Perhaps it may be related to their generally poorer level of education (hence lack of awareness of the benefits of such improved farm practices) and/or the fact that many have insufficient milking cows hence must rely on non-dairy enterprises to generate their farm income. Not being "full time" dairy farmers possibly reduces their time and motivation to actively seek and adopt new information and technology.

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Traditional dairy farm management practices are not conducive to high levels of stock performance or farm profits, as is evident from many studies throughout Asia (Ahuja *et al* 2012, Falvey and Chantalakhana 1999, Moran 2005). The following lists many of the typical measures of herd performance on traditionally managed small holder dairy farms in the humid tropics:

- 10 kg/cow/d of milk yield, compared to a realistic15 kg/cow/d
- 15 to 18 months calving interval, instead of 12 to 15 months
- 30 to 33 months age at first calving, rather than 24 to 27 months
- 2.5 or more services per conception rather than a realistic 1.8 to 2.0
- High mortality rates in young stock, often with little diagnoses of the causes
- Many cows suffering from obvious climatic stress, as is evidenced by respiration rates exceeding 70 breaths per minute
- High levels of subclinical, as well as clinical, mastitis
- High incidence of lameness
- High incidences of animal health problems due to poor veterinary support and subsequent practices
- Unacceptably high levels of bacterial contamination in fresh milk delivered to milk collection centres

Many of the above Key Performance Indicators (KPI) are a result of poor management practices, and will be discussed later. However they are also the outcomes of deficiencies in the farm's physical layout, which will not be fully addressed in this review, such as:

- Insufficient year-round supplies, or provision of clean drinking water, for *ad libitum* intakes
- Insufficient areas for on-farm forage production
- Cattle housing not conducive to cow comfort, for example poor shed ventilation, absence of fans and minimal provision of rubber mats for stock to lie on
- Tie stalls rather than free stalls or open lounging

This review will address improvements in farm management of SHD which are likely to lead to better cow performance hence improved farm profits. They will be discussed in a prioritised list based on their relative input costs and farm returns.

Improving cow comfort

A relatively new term has been introduced to the lexicon of dairy farming, namely "cow comfort".
This term describes the cow's wellbeing, which covers both

- physical (physiological) needs, such as relief from environmental stress and ability to rest when desired, and
- psychological needs which include minimising the adverse effects of pain and fear.

The complete definition of cow comfort addresses climatic stress, poorly designed and constructed housing and stock facilities and potential behavioural stress from herd mates and stock people. It could simply be defined as the cow being "at peace" with her perception of the world. Cow comfort for walking, standing, exercise and lying are essential for healthy and mobile cows. Research has shown that up to 20% of the cow's potential is determined by how comfortable she is and whether her demands are being met (Moran and Doyle 2015).

Milk production and reproductive performance of dairy cows are directly related to their intake of feed nutrients which depend on two major aspects. First, provision of these nutrients in the form of adequate amounts of quality forages and concentrates and second, the cows' desire to want to consume them (i.e. their appetite). Cow comfort has a major impact on this second aspect such that, excluding feed quality factors, depressed appetite is largely the result of poor farm management practices. Under traditional forms of dairy herd management, appetite invariably suffers because of many of the observations discussed below. Feeding for refusals, pushing up feed and maintaining free stalls were cited as the main factors accounting for differences in milk yield among dairy farms with cows of similar genetic composition fed the same diet (Bach *et al* 2008).

In addition to maintaining cows within their "comfort zone" or climatic zone of thermoneutrality, one major objective in optimising cow comfort is providing adequate opportunities for stock to comfortably rest, undisturbed, for lengthy periods of time (up to 12 to 14 hours per day). In addition, routine herd management should not induce unnecessary pain and the behaviour of the cow handler should not elicit fear that leads to negative behavioural responses in stock.

A comfortable cow is then one that, being at peace with her surroundings, should potentially respond positively to more intensive feeding and herd management. Because her appetite is not limiting, any resultant additional feed nutrients offered and consumed should produce more milk and achieve the positive energy balance required to conceive her next calf. In general, the simplest assessment of cow comfort is up to a point, if she is offered more feed, she should choose to eat it and positively respond with higher production.

Addressing the combined effects of high temperature and humidity

Dairy cow performance is adversely affected in the tropics by the combined effects of high temperatures and high humidities. The degree of heat stress is best quantified using the Temperature Humidity Index (THI) which is based on actual measures of these two variables in the cow shed. Threshold values have been developed above which cows will reduce appetite and show evidence of heat stress and abnormal metabolism. It is of interest to note that in recent years, threshold THI values have decreased, from 72 to 68, possibly because of the improved genetic merit of dairy cows worldwide to produce more milk and the increasing number of hours per day that they are likely to experience heat stress (Young 2015, Zimbleman *et al* 2009). Some people might argue that this is the result of recent evidence of global warming.

In addition to reducing appetite and hence milk yields, heat stress in milking cows has been shown to decrease lying times and reduce the proportion of saliva reaching the rumen resulting in decreased ruminal pH; this increases the risk of subclinical rumen acidosis (West 2003). Heat stress also impairs reproductive success through both greater pregnancy losses from 21 to 30 days

of gestation and more inseminations required per successful conception (Hansen and Arechiga 1999). Heat stress increases time spent drinking, the incidence of lameness, cull rates and even cow mortality rates. It also changes the energy metabolism in the cow by reducing body fat mobilisation and increasing muscle breakdown; this can reduce the cows' ability to stimulate milk production in early lactation by repartitioning energy from the mammary gland to body reserves (Baumgard and Rhoads 2012, Wheelock *et al* 2010).

More recent evidence indicates that heat stress can have long term detrimental effects during the cows' dry period in that heat stressed dry cows have depressed appetites, lose more body condition and have reduced immune function to combat disease/infections (Tao and Dahl, 2013). Their milk yields are also adversely affected during their next lactation. In addition to this, calves born to these heat stressed cows have lower birth weights, growth rates and reduced immunity, through lower absorption rates of maternal immunoglobulins from the colostrum to their blood stream, which may be a factor in their higher pre-pubertal culling rates (Tao and Dahl, 2013). This is associated with reduced milk production and more inseminations per successful conception as mature cows. These recent findings clearly indicate the importance of paying much closer attention to heat abatement procedures in pregnant, dry cows.

Mating heifers can respond to heat abatement following just 4 hours of cooling using fans and sprinklers which has been shown to increase their pregnancy rates from 23% to 57% (Moghaddam *et al.,* 2009). Herd bulls are also adversely affected by heat stress through reduced spermatozoa counts; this occurs 6 to 8 weeks following the heat stress period.

One reproductive technology that appears unaffected by heat stress is embryo transfer. Initially oocytes are susceptible to heat stress for several days after ovulation and will not develop. However, by day 6 to 8, these oocytes have developed their own heat tolerance and can be collected, fertilised and put back into cows with good pregnancy rates.

Heat stress needs to be addressed with a combination of management practices. Of greatest importance is fresh drinking water, which will be discussed in a later section. Additional minerals, particularly sodium, potassium and magnesium need to be provided to compensate for higher losses through increased respiration, drooling and sweating (West 2003). Improving shed ventilation, another essential practice will also be discussed in a later section.

Feed fewer cows better

Impacts on milk yields and feed efficiencies

On most traditionally managed SHD farms, low per cow milk production and poor fertility are frequently the results of too many animals on too small a farm area It is always energetically more efficient to feed fewer cows better. This was demonstrated dramatically by Moran (2005) in a series of theoretical calculations on the optimum number of milking cows (plus their replacement heifers) to produce the same annual yield of milk. For example, an annual yield of 50,000 L of milk, can result from any of three herds; 10 cows each producing 5000 L, 13 cows each producing 3846 L or 17 cows each producing 2941 L/year. The energetics of these scenarios are shown in Table 1.

These energy requirements are expressed in MJ/L milk of metabolisable energy. To produce the actual milk, the cows only require about 5 1 MJ/L milk (depending on milk composition). However, this increases to 8.9, 10.0 and 11.5 MJ/L milk respectively after taking into account maintenance requirements, repartitioning of body reserves in early and late lactation and their requirements for pregnancy during lactation. After taking into account their energy requirements during the dry period and for the growth of the heifer replacements, this increases to 11.0, 12.8 and 15.0 MJ/L milk produced for the herds of 10, 13 and 17 cows respectively. From Table 1, the higher yielding cows have a great proportion of their dietary energy directed towards producing milk, rather than all the other associated energy costs of being a lactating dairy cow in a self-replacing herd.

Clearly more milk per cow is much better than more cows per herd to produce the same amount of milk. Having more cows per herd generally leads to less fresh forage fed per cow because most of these SHD farms are overstocked because farmers aim to maximise herd size. Feeding less forage means either producing less milk and/or spending more on purchasing more expensive formulated concentrates to make up the nutrient shortfalls. So this justifies one of the major objectives of SHD farming, namely feeding fewer cows better.

Impacts on dairy herd makeup

Adult cows are either lactating (wet) or non-lactating (dry). In the process of their full lactation they are either non-pregnant or pregnant. Pregnancy status is best determined through pregnancy diagnosis (that is an internal examination of the uterus by an experienced technician or veterinarian) but can also be ascertained by

Table 1: Annual metabolisable energy audit for 3 herds producing 50,000 L/year of milk

	Herd size		
	10	13	17
Total milk yield (L/cow/yr)	5000	3846	2941
Average milk yield (L/cow/d)	16.7	12.8	9.8
Daily energy requirements (MJ/d)	148	128	113
Energy for maintenance (%)	40	46	52
A. Total farm energy for milk prod ('000 MJ/300d)	444	499	576
Daily energy cost to produce milk (MJ/L)	8.9	10.0	11.5
B. Total farm energy for dry period ('000 MJ/65 d)	39	51	66
C. Rearing heifer replacements ('000 MJ/yr)	66	88	110
Total farm requirements = *A+B+C* ('000 MJ/yr)	549	638	752
Productive feed energy (%) = *A/(A+B+C)*	81	78	76
Total energy cost to produce milk (MJ/L)	11.0	12.8	15.0

"return to service" (that is whether the cow cycles in about 21 days since she was last inseminated or serviced by a bull).

Each cow can be categorised as follows:

1. Wet and non-pregnant (W/NP) from when the cow calves to when she conceives, usually some time during early lactation.
2. Wet and pregnant (W/P), from conception to when the cow is dried off (either naturally or through management).
3. Dry and pregnant (D/P), between drying off and calving; this determines the minimal length of the dry period.
4. Dry and non-pregnant (D/NP), which should not occur but unfortunately often does

The proportion of cows in each category depends on two major factors, namely the number of days from calving to conception (which is greatly influenced by the days from calving to first service and the number of services per conception) and the lactation length. Clearly the earlier that cows conceive after calving, the greater the proportion of time that they are pregnant during lactation, and the longer the lactation period, the greater will be their income from milk production (Moran 2015). The ability of cows to cycle soon after calving and to milk for longer periods are both highly dependent on their nutrient intakes. Therefore both these goals will be achieved through feeding cows better. With limited feed resources, this often requires decreasing herd sizes. Certainly any dry, non-pregnant cows should be first on the culling list.

Improving time management of small holder dairy farms

Many changes in management practices have negligible costs apart from spending more time on any one task. Most SHD farmers do not include the financial value on their own time and labour in calculating their total cost of milk production. Such accounting procedures are usually in the form of their opportunity costs, or the monetary return per hour, day or week that the farmer could earn if he/she spent that time being paid to do other work (that is the opportunity cost of their farm labour), or what it would cost them to employ someone else to do all or part of their job as a dairy farm operator (Moran 2009).

Improving traditional management practices often requires more time spent on each task, but in some cases, it can actually reduce labour inputs at a later date, as can be the case for the first two items listed below.

Observing cows on heat

Time should be spent on watching for oestrus expression of cows in order to inseminate them (either artificially or through natural mating with a bull) at a time when they can become pregnant. These observations should be made frequently, particularly outside normal working hours such as during the cool of the evening or early morning. This is very important in the humid tropics where the length of the heat period can be as short as 4 to 6 hours. More frequent observations mean a better chance that cows will initially be detected to be in heat early in their oestrus period rather than later on, when any delays in actual insemination will reduce the chances of a successful insemination and requires fewer inseminations per successful conception. This is one of the KPIs of dairy cow fertility mentioned above.

Colostrum feeding management

In many cases, improvements in herd management practices do not actually increase farm labour input, but they simply lead to a more strategic timing of that practice. One good example of this is ensuring new-born calves consume sufficient quantities of good quality colostrum within a few hours of birth when it is absorbed into their blood stream. Farmers attending a birth should then develop a routine of feeding colostrum to the calf as well as cleaning it and separating it from its mother soon after birth. Provision of colostrum through a bottle plus teat or a stomach tube will ensure that the calf can actually consume the required colostrum rather than depending on her mother to allow it to be suckled directly from her teats. Inadequate quantities of consumed colostrum do not provide sufficient immunity, essential for every calf to cope with the exposure to pathogenic microorganisms present in any calf shed.

In this case, a few more minutes spent immediately following the calf's birth often saves many more minutes or even hours spent treating her later on during the milk rearing period. Furthermore, calves with adequate immunity will generally outperform calves that are short on maternal antibodies (supplied through the colostrum) through lower incidences of diseases. This results in faster growth rates as young heifers, younger ages at first calving, higher lifetime milk yields as mature cows and greater longevity in the milking herd. All of these are desirable KPIs on farms with good young stock management. So more time spent within the first few hours of birth will reduce labour requirements in later life as well as reduce herd costs hence increased farm profits.

More frequent forage harvesting

Tropical forages can grow very fast between harvests and mature quickly. Under traditional management, the number of days between harvestings, called the harvest interval, is often far too long, a conscious decision to maximise the forage yields. Milking cows need high quality forages, hence lengthy harvest intervals (such as 60 days or more for Napier grass) results in forages with lower concentrations of digestible energy and protein. Such forages also contain too much lignified fibre which reduces both the rate and extent of forage digestion. This results in greater rumen fill which reduces appetite. Although more frequent harvest intervals increase farm labour inputs and produces less total forage DM/ha, long term this will lead to improved milk yield per kg forage consumed and improved digestible DM yield of forage. This is an obvious KPI to aim for.

Wilting freshly harvested forages

Freshly harvested tropical forages can have very low DM concentrations. Wilting the chopped forage increases its DM content and in so doing, will stimulate appetite. Moran and Mickam (2004) wilted Napier grass for 8 hours post-harvest, which increased DM contents increased 17 to 20%. Intake of fresh grass increased by 10 kg (from 40 to 50 kg/cow/day), and total DM intakes (including concentrates) rose from 12.2 to 15.4

kg/cow/day. This provided additional nutrients that increased milk yield from 14.2 to 15.7 L/cow/day. Clearly such a simple and practical change in post-harvest feeding management can stimulate forage intakes, total feed intakes and milk yields leading to increased profitability. This can be accomplished through simply constructing wilting racks from bamboo poles, even though you have to double handle the forages.

Providing a year round supply of quality forage

Without supplemental irrigation, forage growth depends largely on rainfall, which is very seasonal. Ideally, wet season flushes of forage production should be harvested and conserved for feeding during the following dry season. This practice reduces forage shortages and reduces the need to purchase additional concentrates that would otherwise need to be fed to provide a more even supply of feed nutrients throughout the year. Forage conservation can take the form of hay or silage. Hay requires many consecutive rain-days, which is rare in the wet season. Therefore silage is the only way to plan for and provide dry season forages.

On the whole, traditional dairy farmers want to handle their hand harvested forage just once between harvest and transport to the cow shed. Double, or triple handling of the same forage is considered an undesired chore, even though it can improve nutrient intakes, milk yields, fertility and profits during the dry season. Silage making has been promoted in many Asian countries by many international, local government and private agencies, over the last two or three decades with very little success in its adoption at the SHD farmer level. Even though it could be very beneficial to individual SHD farmers, it is obviously rarely considered so, hence its lack of adoption.

Improving shed hygiene

Far too many small holder dairy sheds have inadequate floor cleaning protocols. Cows that are forced to lie in manure or on extremely dirty floors have poorer milk quality (Moran 2005). Thoroughly cleaning out cow sheds at least twice each day will reduce this contamination during the milking process. Shed effluent needs to be directed to a central location for ease of handling so it can be recycled back onto the forage production area and reduce fertiliser costs (Moran 2009).

Others

There are other time minimal farm inputs that can improve work efficiency, cow performance and farm profits. These include

- Stimulating intake of freshly harvested forages through hand or mechanical chopping in conjunction with removing feed residues several times each day
- Learning how to and adopting the correct hand milking techniques to minimise contamination of the freshly harvested milk in the bucket. These include not washing cows udders and backs, just their teats, when preparing the cow for hand milking and also not pulling down (just squeezing) on the teat during hand milking.
- Ensuring the "Use By"/Expiry dates/Correct handling and storage are all adhered to with veterinary drugs
- Adopting and using a farm and herd recording system and keeping it current on a daily basis
- Thoroughly mixing formulated concentrates by spreading each ingredient out one by one on a clean concrete floor then using a spade to vertically collect the mixture to place into the storage bag.

Investing in improved farm management

We all know the saying that "you must spend money to make money". However, all too often farmers are reluctant to spend money on improving farm facilities, equipment and consumable items. Unfortunately there is an overriding poverty mentality on many SHD farms in Asia. This is not disputing the fact that these farmers often have a very small cash flow from which to provide for their family as well as their farm requirements. This is because traditionally, such farmers consider spending money to be a farm cash expense. Rather, it should be viewed as a farm cash investment. Granted before any money leaves the farm for such items, farmers need to assess the likely farm benefits arising from that financial input. That is the same as in every commercial business transaction. Below are some examples of potentially good farm business decisions.

Purchasing formulated concentrates

There is also a saying that "you get what you pay for". For SHD farmers, the classic example is purchasing formulated concentrates. Time and time again the managers of feed mills owned by dairy cooperatives report that the most common milking cow formulated concentrate is the one with the lowest crude protein content, simply because it is also the cheapest. Some dairy cooperatives offer a range of formulated concentrates, such as those containing 14, 16 or 18% protein. These are provided for different classes on dairy stock, such as low yielding, high yielding milking cows and growing heifers. One example of the costs for these particular formulations, is from a West Java dairy cooperative in November 2015 (Moran unpublished data). The costs were 2400, 2700 and 3200 Rp/kg for these concentrates containing 14%, 16% and 18% protein respectively. With the current exchange rate for the Indonesian rupiah being 13650 Rp/US$, this is equivalent to 17.6, 19.8 and 23.4 US cents/kg, respectively. Approximately 97% of the concentrate sales were for the 14% protein formulation. Farmers were simply not prepared to invest in higher quality concentrates even though their milking cows and growing heifers would greatly benefit from the higher protein formulation.

With their cows producing on average 11 L/cow/day of milk and being fed up to 8 kg/cow/day of concentrates, and that milk returning 5000 Rp/L (or an equivalent of 36.6 US cents/L), it would be possible, from on-farm production data, to calculate the cost: benefits of investing in a higher protein concentrate. However, it is not possible to state categorically that higher quality concentrates would invariably lead to higher milk yields.

However, growing heifers require a ration containing on average 16 to 18% protein, and that includes the forage component as well as the concentrates (Moran 2012), hence ideally they should be fed on the highest protein concentrate. The major conclusion that can be drawn from these observations is that milk yields and heifer growth rates are highly likely to be limited by nutrient imbalances/inadequacies in their total ration.

Purchasing fertilisers for forage production

Another good example of "you get what you pay for" is purchasing inorganic fertilisers (such as urea) for use in the SHD forage production area. The lack of adoption of this practice is one the major limitations of forage production on most SHD farms in SE Asia. From a series of calculations of typical annual forage consumptions and milk yields of dairy cows in the humid tropics, Moran (2005) concluded that in addition to recycled shed effluent, the forage crop would require at least an additional 100 kg N/ha/yr of urea fertiliser. This is likely to be even higher because of losses of nitrogen from urine through volatilisation and leaching. This conclusion is supported by local research findings on increased yields and nutritive values of Napier grass fertilised with different rates of urea. Aminah and Chen (1991) concluded that the optimum annual level was 300 kg N/ha/yr, split into five equal applications over the whole year. Fertilisers cost money, but they return more through improved yields and quality of forage, hence more milk. In fact, STOAS (1999) concluded that urea fertiliser can grow an extra 9 kg forage DM/kg urea and when harvested and fed to milking cows, this extra forage would yield an additional 9 L milk/kg urea N. From local fertiliser costs and unit milk returns, readers of this review can easily calculate a cost: benefit analysis of this improved management practice.

Providing adequate clean drinking water

As ambient temperatures increase from 7 to 18 to 29 ^{o}C, voluntary water intakes in lactating cows increase by 13 and 26% respectively. The water requirements of dairy cows are grossly underestimated on most traditional SHD farms. Each lactating cows requires 100 to 150 L per day while dry cows require 50 to 60 L/head/day, with at least 50% of this to be provided within one hour of the cows eating or being milked.

All too frequently, milking cows are only offered limited quantities of water several times each day. Some farmers only offer their cows a slurry of concentrates plus water, meaning that the cows are not even provided with clean drinking water. Surely that would lead to lower water intakes.

Improving shed ventilation

Increasing the air movement across the milking cows is an essential part of improving cow comfort. For a small herd of cows, house fans (either on tall stands or small ones for placement on shelves) might be sufficient. One fan could be used to cool several cows if it is located high enough in the shed. It would be preferable to select newly calved cows to be closest to these fans as their internal body heat production would be the greatest, hence they would be the most susceptible to heat stress. Monitoring respiration rates throughout the day should provide a guide to the adequacy of increasing the shed's air movement. A rate of 70 breaths or more per minute would indicate heat stress. Using a hose to spray a rapid flow (not of fine water droplets) of water onto the backs of heat stressed cows will also aid in cooling them.

Purchasing rubber mats

For cows to rest for their required 12 to 14 hours each day, they need a comfortable bed. Concrete floors are insufficient. Rubber mats are ideal for tie stalls and free stalls, with the thick 15 to 20 mm thick sponge rubber mats being the most ideal. There are other types of bedding that can more easily be used in free stalls, such as saw dust, sand, even rice hulls, but they require additional labour input to maintain their cleanliness hence hygienic state. Rubber mats can seem expensive but they will return their investment within a year or so through improved milk yields and fertility.

Feeding calf milk replacer rather than fresh milk

As farmers try and maximise the volumes of milk they can sell every day, they inadvertently waste money on feeding this milk to their baby calves. In most Asian countries, where it is available to purchase (and it is of good quality), a solution of Calf Milk Replacer (CMR) is usually a cheaper alternative liquid feed for the first few months of life. Certainly this is the case in Malaysia where Moran and Brouwer (2013) compared the two liquid feeding systems. They reported that CMR powder costs Malaysian ringgits or MR 6720/t and makes 7690 L of CMR solution (at 130 g/L solution), therefore costs MR 0.87/L solution. The exchange rate for the Malaysian Ringgit is 4.4 MR/US $. Raw milk sold for MR 2.40/kg or MR 1.63/kg more. Therefore, for a milk-fed calf fed 2kg/d of milk over a 12 week period, using CMR provides savings of MR 274/calf. That is a considerable saving in unweaned calf rearing costs.

Milk-fed calf facilities

Ideally milk-fed and young weaned calves should be housed separately from older stock and in very small groups, to minimise transfer of diseases. The best facility is a set of individual calf cages so calves can easily see each other. Being off the ground, staff can more easily feed and attend to each animal while the cages can be easily cleaned and maybe even sterilised in the sun between calf usages. Three buckets can be provided per cage, one for water, one for milk (fed once per day and not via a teat) and another for dry feed (concentrates and maybe with small amounts of dried roughage to stimulate rumen development). The calves can be weaned off milk when consuming 1.0 kg calf concentrate each day, this occurring by no later than 6 to 9 weeks of age.

Suckling calves on their mothers

Another traditional management practice frequently observed in the tropics is allowing calves to suckle their dams. During discussions with farmers who practice this activity, they invariably argue that this is the best way of encouraging milk letdown prior to milking the cow, usually by hand. Such farmers make little effort to separate cow and calf soon after birth hence the cow/calf

maternal bond quickly develops. This certainly inhibits a rapid letdown of milk by the cow if the calf is not present, thus justifying the farmers' approach.

On some farms, this practice could continue for up to 9 months, costing the farmer much money through lost sales of raw milk. Using the same Malaysian feed costs as those above, and assuming a suckling calf drinks 3 kg raw milk/d for 9 months, or 810 kg over 9 months, Moran and Brouwer (2013) calculated that it costs MR 1944/suckling calf. By rearing the same calf on 2 L/calf/d of CMR solution and weaning it at 4 months, total CMR costs were MR 146/calf. In addition, the daily feed cost for yearlings was assumed to be MR 2.46/d or MR 369/weaned heifer over 5 months (although this would be for yearling heifers). Total feed costs were then MR 515/ for each CMR reared calf versus MR 1944 for calves that suckled their dams. This was a saving of MR 1429 for CMR versus suckled calves. Granted there would be a difference in calves' live weight at 9 months of age between these two calf rearing systems (because of their vastly different feeding programs) but in the long run, such a tradition of suckling calves on their mothers for 9 months is very costly to the farmer.

Milking hygiene

Hot water is essential for proper cleaning and sterilising of milk handling equipment. For bucket milking machines, the rubber liners must be replaced every 2500 uses (to reduce teat irritation and decrease mastitis causing organisms). All milk handling equipment should be hung upside down to allow it to drain, and dry hence kill the bacteria in between milkings. Cows' teats should be sprayed or dipped in iodine solution following milking then offered fresh feed to encourage them to stand for at least 30 minutes so as to ensure the teat canal closes so pathogens cannot invade the udder tissues.

Using towels on multiple cows to wash teats before milking can be a major cause of spreading contagious mastitis microorganisms. Ideally each cow should be cleaned with a separate clean towel which is then discarded until it has been washed in sanitiser, then hung up to dry thoroughly until next used.

Identifying cows with high levels of somatic cells is necessary to monitor for mastitis. The California Mastitis Test is a test that measures somatic cells and is commonly used throughout Asia. However it is still not universally accepted as an essential component of any mastitis management plan. In addition dry cow therapy, using a slow release antibiotic at drying off, should also be universally practised.

Utilising local farmer services provided

When farmers join dairy cooperatives or become suppliers for particular milk processing companies, they are provided with the services, many of which are supplied freely. It is of great benefit to these farmers to make full use of these services. Of great importance is the development of a good working relationship with the veterinarian attached to these agencies. The key role for veterinarians is to provide for animal health needs. The saying "prevention is better than a cure" is very relevant to SHD farmers because many animal health issues that arise can have been more easily addressed after the farmer and veterinarian have jointly developed a farm plan for the routine health management of all their dairy stock; this includes young stock as well as adult cows. Such a plan should include learning to recognise early symptoms of ill health, whether as a result of poor feeding management, local infectious agents, or any other cause. Such a training program should include all farm staff.

A farm animal health recording system is part of the record system mentioned above and also includes insemination records. This should be developed whereby staff can note any unusual stock behaviour. Keeping farm production, farm purchases and business records is the first step towards developing a database on cow performance and farm profitability. Only then can more objective decisions on long term farm planning be made. The saying that "if you can measure it, you can manage it" also means that "you cannot manage something that you have not recorded".

Improving the shed layout

As already mentioned, shed comfort can have a major impact on appetite hence cow performance. However, it often comprises the highest capital investment in improving farm management so should be carefully budgeted. But keep in mind that:

- Optimising the shed environment is paramount to minimise any likely stresses on dairy stock.
- There are often relatively low cost improvements, such as removing solid walls that hinder air movement within the shed.
- A good non-slip surface for cows to walk on is important, as it allows for more confident movement and less chronic hoof problems. It should also have a good slope on it, for ease of cleaning.
- Provision of adequate clean drinking water is essential. Ideally it should be offered *ad libitum*, with water troughs regularly emptied and cleaned out. A set of pipes and syphons attached to a single sump with a float valve are ideal for tie stalls so every cow can have fresh water when desired.
- Recycling shed effluent can be undertaken in many ways, but directing the effluent into water, to reduce volatilisation of nitrogen from the urine, followed by pumping the effluent to the forage production area, is the most time efficient system.
- An outside yard, covered with sand for ease of daily cleaning, is an important shed improvement so stock can cool down and "stretch their legs" at night. It will also help with identifying cows in heat in sheds where the stock are only provided with tie stalls.
- Veterinary drugs should be stored in a locked dark cupboard, and if required, inside a refrigerator.
- Gutters and downpipes leading to drains or water storages will allow more effective control of rainwater and if directed into large containers, also provide a potential source of clean drinking water.
- Biogas provides energy for heating water for washing milk handling equipment as well as providing cooking gas for domestic purposes. In some countries, there are government/private companies that provide financial incentives to install biogas units.

- Vermin proof and insect proof sheds for essential for storing feeds.
- Increasing the height of a low roof will improve ventilation but this may require large capital outlays.
- Replacing tie stalls with free stalls or even open lounging, will improve cow comfort hence the herd's response to other improved management practices.
- A birthing pen, or at least an area of the shed that can be cleaned, sterilised and used specifically for calving, is essential for newly born calf handling and hygiene.
- If using natural mating, a separate mating pen should be provided.
- A hospital/isolation pen should be provided for confining animals in heat, artificial insemination, routine health checks, pregnancy diagnosis and examining sick cows.
- A cattle race, crush and/or head bale or other ways of immobilising stock are important both for the stock (to reduce stress) and the staff (to reduce injury).
- Foot baths should be considered for routine hoof treatment, at least 2 to 3 m in length and 0.15 m deep
- Trees and shrubs could be planted around the cow shed to reduce the heat load from the sun. Without inhibiting natural ventilation of the shed.
- Painting the roof white will improve its deflection of solar heat
- Having a designated office area, which could also be used for farm staff to relax during work breaks, will improve work efficiency.

Renovating cow sheds

It is often just as expensive in the long term to renovate old buildings that have been originally built for other livestock species or for a smaller dairy herd, than to remove the building entirely and start with a greenfield site. When designing new buildings, consideration should be given to future expansion plans by ensuring sufficient space around them as well as adequate provision of utilities such as water, electricity and shed drainage.

Ideally buildings should be located above the 1 in 100 year flood level and all earth works should be designed to avoid off site impact of floodwater discharge either through funnelling or backwater effects. The natural drainage regime of the area must be considered so that uncontaminated rainfall runoff can be easily diverted away from the effluent storage.

The ideal aspect of the buildings depends on its geographical location. Buildings should be orientated to maximise prevailing winds and minimise exposure to sun light and rainfall. Locating the shed perpendicular to prevailing winds aids cross ventilation. A north-south orientation promotes drying in exposed areas because the shade moves across the shed during the day.

Conclusions

Virtually every country in Asia has a national dairy development program promoting increased milk production. This is natural progression from the decreasing national self-sufficiencies in liquid milk and dairy products occurring throughout the region. School milk programs, increasing levels of affluence, the greater desire for "more western food" and the expansion of modern retail outlets, with refrigerated cabinets throughout Asia, have resulted from the more widespread knowledge of the nutritional benefits of dairy products. Although there is increasing emphasis on developing large scale dairy farms (Moran and Morey, 2015), the future of Asian dairy farming will remain in the hands of the millions of SHD farmers for many years to come.

Many of the above improvements in traditional dairy farm management and practices are slowly being adopted and this will increase into the future. Furthermore, many of these do not require a great deal of change in the daily costs of producing milk and with the increased cow and herd productivity, will greatly reduce the total per unit costs of milk production on many existing farms. As more farmers adopt these improved practices and others are "looking over their shoulders", the most beneficial ones will become more prevalent. In areas destined for new dairy farming as part of the regional development programs, there are also many lessons to be learned from the past so as not to repeat the same mistakes again.

There are other production technologies, particularly nutritional, that have been evaluated on dairy farms in the humid tropics, such as ammonia treatment of low quality forages and crop residues, feeding urea-molasses-multinutrient blocks, urea supplementation, enzyme treatment of forages and feedstuffs and particle size reduction. However adoption rates have been very slow often because of non-nutritional reasons. These include additional cash required to purchase inputs and/or additional labour requirements to implement the technology, both of which have been used to justify poor adoption of many of the above mentioned improved management practices. Other reasons for poor adoption include poor economic returns for using the technology, lack of facilities or equipment or other issues. Larger farms may be in a better position to adopt some of these technologies since their cash flows and labour resources are not as limiting (Bernard 2015).

This review has prioritised these improved practices. It is now up to the many dairy stakeholders in Asia's humid tropics to disseminate them throughout their dairy industries. It would be nice to say with confidence that the days of traditional SHD farming production systems will soon be over. But at least we can be confident that the international aid agencies and national government and commercial dairy stakeholders are all providing avenues for dissemination through the formation of websites such as the Asia Dairy Network (http://www.dairyasia.org).

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