Trop Anim Health Prod (2013) 45:1079–1086
DOI 10.1007/s11250-013-0372-9

REVIEWS

Optimum use of milk in traditionally managed cattle herds in the tropics

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Accepted: 29 January 2013 / Published online: 12 March 2013

Abstract In traditional cattle systems in the tropics, the milk produced is generally shared between the calf and the cattle keeper. This literature review evaluates the socio-economic aspects related to milk production and milk use in traditional cattle systems and identifies the best strategies of milk allocation in order to improve food security and maximise income. The available literature indicates that milk, in terms of economic, social and subsistence value, is more valuable than meat. Thus, under the conditions that characterise traditional cattle systems in the tropics, it is appropriate to have a higher milk offtake at the expense of calf growth. This review also found that certain management practices, such as restricted suckling, can be useful to minimise mortality of calves, while improving milk offtake for human consumption.

Keywords Herd management · Calf growth · Milk offtake · Socio economy

Introduction

Cattle kept under traditional production systems still support the livelihoods and household food security of millions of people in rural areas (FAO 2009). Dual-purpose systems in Latin America and pastoralist systems in Africa exemplify this statement by generating food and income mainly in the form of milk and meat. In tropical conditions, it often becomes more profitable to raise animals with intermediate levels of production of both beef and milk since cattle have, on average, lower milk yields and lower weight gains (Preston 1977). Besides, traditional systems are more appropriate for the resource-poor since they have a reduced sensitivity to price variations (Holmann et al. 2003), improved adaptability to resources, high flexibility and require a lower capital investment (Rivas and Holmann 2002). Combining milk and beef production, though, has some drawbacks: low milk yields of dual-purpose breeds, high labour costs and potential reduction of calf growth due to milking (Jarvis 1988).

In traditional cattle systems, the milk produced is typically shared between the calf and the cattle keeper. Milk can be used for household consumption or sale, traded for other foods, or given solely to the calf to enhance the conversion of milk into beef (Sadler et al. 2010). Milk and meat, therefore, compete. The challenge for traditional cattle keepers is to minimise mortality and improve growth rate of the future milk and meat producing stock, while maintaining a good milk offtake for human consumption. In other words, the calf has to have an appropriate growth rate at a tolerable cost (Ouologuem et al. 1994). In order to achieve this end, it is common that traditional cattle keepers practice restricted suckling, whereby after the hand milking of the dam, the calf is allowed to strip out the remaining milk (de las Heras-Torres et al. 2008).

This aim of the present literature review is to evaluate the socio-economic aspects related to milk production and milk use in traditional cattle production systems in the tropics and to identify the best strategies of milk allocation in order to improve food security and maximise income.

Socio-economic evaluation

Milk production

Milk is an economically feasible co-product in traditional cattle systems whenever there is enough demand to support

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the costs of milking and specialised milk production is not possible because of unfavourable climatic conditions (Jarvis 1988). Unlike beef, milk is a renewable product which is available every day; meat is the end product of cattle production, available only occasionally when the cattle are slaughtered (Sadler et al. 2010). Suttie (2001) stated that compared to any other arid zone production system, milk can directly support, on a subsistence basis, significantly more persons per unit area.

As opposed to specialised beef production, milk ensures a regular flow of income through milk sales while conserving the herd capital (Holden et al. 1991; Bartl et al. 2009). The dairy income can be used to cover part of the costs of keeping the cow to produce the beef calf, consequently reducing beef production costs, or to support daily household needs. The regular income from milk sales is particularly important for producers with restricted access to formal credit and scarce cash and capital (Jarvis 1988). The milk money is also important for women since it is often their sole revenue from the system (Holden et al. 1991). In most cases, it is the woman who decides the amount of milk to put on the market and how to use the revenue from milk sales at the household level (FAO 2006).

Milk from livestock is the traditional staple food for pastoralists in Africa (Coppock and Sovani 1999; Sadler et al. 2009; FAO 2011b). The consumption of milk and milk products among pastoralists varies significantly according to the season and ethnic group, but it was found to constitute more than 50 % of the diet of the Masaai, Rendille and Turkana of Kenya and Tanzania, the Borana of Southern Ethiopia and the pastoralists of Koch County in South Sudan (Galvin 1992; Galvin et al. 1994; Lindtjørn et al. 1993; Homewood 1995; cited in Sadler et al. 2010; Barasa et al. 2008). Some pastoralists in Africa rely on cattle milk not only as a dietary mainstay but also as a means of income generation. Thus, herdsmen strongly compete with calves for milk (Cossins and Upton 1988a); milk offtake may be up to 65 % of the dam's production (Holden et al. 1991). This competition for milk is considered as one of the causes for the poor livestock productivity in pastoralist traditional cattle systems in Africa (Cossins and Upton 1988a). Calves under such systems generally have low growth rates, delayed puberty and high mortality (Okantah 1992; Moran 2011). Depriving the calf of an excessive amount of milk through milking will benefit the pastoralist in the immediate, but in the long term, it will affect growth rate and herd replacement (Western and Finch 1986). Therefore, the pastoralist has to find an equilibrium between his present and future needs (Spencer 1965).

Milk use

In traditional cattle systems, the producer may decide, according to market demand, whether to enhance the production of milk or the production of beef by applying different suckling and milking regimes (Sandoval-Castro et al. 2000). When the milk price is high, the milk offtake may threaten the survival of the calf (Ouologuem et al. 1994). Nonetheless, its survival is important for the producer; its death results in an unsold calf, interruption (Bazzi and Alipanah 2011) or reduction of milk production by the cow, loss of the money invested in its growth and waste of a future breeding animal (Wymann et al. 2006). Female calves are normally better cared for than male calves (Horowitz 1981), probably because of their future milk output and reproductive function (Mapekula et al. 2009).

According to Cossins and Upton (1988b), in the Borana pastoral system of Southern Ethiopia, it is convenient and justified, in terms of food energy and monetary value, to have a high milk offtake, even if it affects calf growth, reduces herd replacement, determines lower weaning weights and increases calf mortality. The authors illustrated that Borana calves require 4 kg of milk to gain 1 kg of calf live weight (Nicholson 1983) and that 1 kg of milk, in terms of energy or monetary value, is worth more than a kilogram of calf live weight. Cossins and Upton also noted that when milk offtake for human consumption is reduced from 312 l per lactation to 156 l, the monetary value of cow production increased. However, the food energy obtained from meat becomes insufficient to balance the energy lost by the reduced milk offtake. Also, the productivity per livestock unit, in terms of both cash and energy, was found to diminish when reducing milk offtake.

A study carried out in Maasailand by Grandin (1988) reached similar conclusions as Cossins and Upton. The author showed that it is more convenient in terms of nutritional value, gross energy and cash equivalent to allocate milk for human consumption rather than for calves. Grandin assumed, based on previous research, that about 9 kg of milk are needed for every kilogram of live weight gain of the calf and calculated that 9 kg of milk corresponded, in terms of sale value, animal protein and gross energy, to $2.45, 0.3 kg and 33.6 MJ, respectively. In contrast, 1 kg of live weight was equal to $0.73, 0.1 kg of animal protein and 4.1 MJ of gross energy. Therefore, the higher productivity resulting from the increased calf growth is not sufficient to justify the loss of the milk money. Grandin also noted that the attempt of several development projects in pastoral Eastern Africa to transform pastoral systems into specialised beef production systems was shown to lessen job opportunities and productivity per unit area while not meeting the caloric requirements of the community.

In pastoralist societies, milk offtake may increase when the cattle producers have a readily accessible market and advantageous dairy prices (Holden et al. 1991). Milk products, which are an important source of proteins, are frequently sold to buy high-calorie cereals at competitive terms of trade, allowing more people to be supported per unit area of land. Poor families cannot afford to see milk as a

source of proteins since they have to sell it to acquire grains in order to meet their caloric needs (Sadler et al. 2010). Indeed, poorer households are likely to allocate a larger proportion of milk for human consumption and to trade the milk extracted for less expensive food items. The growth in market demand of dairy products encourages pastoralists living in the proximity of urban centres to sell more milk (Sikana et al. 1993). In Ethiopia, dairy marketing was found to be a relevant economic activity for pastoralists who live within 20 km of urban areas (Holden and Coppock 1992). The Maasai pastoralists who live close to Nairobi (Kenya) have 17 % of their income generated from milk sales (Radeny et al. 2007). However, excessive dairy marketing in traditional cattle systems could be to the detriment of the calf and of the nutritional status of the household, in terms of the nutrients contained in milk (Holden et al. 1991).

As mentioned before, the amount of milk available for the calf is largely determined by the economic means of the pastoralist. In poorer households, the few lactating cows available will have to be milked more often to provide subsistence for the herdsman and his family or to provide milk to be put on the market. On the other hand, wealthier households will have more animals, and the offtake that deprives the calf becomes less economically viable; undernourished calves are weaker and reach sexual maturity later (Sadler et al. 2010). In fact, the value of the calves sold by richer households is normally higher than that of calves sold by poorer households (Grandin 1988). Pastoralists in East Africa with many animals milk 35–45 % of their cows. Instead, those with only a few cattle milk 65–75 % of their cows (Upton 1986; Sieff 1999; cited in Lybbert et al. 2004).

The social value of milk and dairy products plays a critical role when pastoralists have to decide how to allocate the milk from their cows. Milk and dairy animals are often used to create and reinforce social bonds among the communities. In some pastoral societies, it is not permitted to sell milk since it must be kept for social gatherings (Sadler et al. 2010). With modernization, these customs and taboos are being lost (FAO 2001).

Management strategies

Calf feeding system

Using *Bos indicus* genotypes for dairy purposes often entails calves being suckled by their dams in order to initiate milk let-down (Das et al. 2000). Even for those cows which do not need the stimulus of their calf, suckling is a good practice since it reduces the risk of mastitis (González-Sedano et al. 2010; Phiri et al. 2010), fastens milk let-down and increases milk yield (Combellas and Tesorero 2003; Yilma et al. 2006). Suckling and milking have to be properly managed as they affect milk production (Leon and Vaccaro 1984), milk quality (Boden and Leaver 1994), cow (Fröberg et al. 2007; Escobedo-Amezcua et al. 2010) and calf performance and calf behaviour (Day et al. 1987).

A suckling regime which does not impair calf growth is to allow the calf to be suckled by the dam ad libitum before milking. This method though is not recommended for traditional cattle keepers since it excessively reduces milk offtake. Coulibaly and Nialibouly (1998) found that calves under this suckling regime consume up to 98 % of the milk produced by their dam. According to the same study, if calves are allowed to suckle ad libitum before milking for the first 3 months of lactation, and the cows are partially milked thereafter, calf growth is not notably different from the ad libitum suckling method while allowing milk offtake. The authors stated that the latter regime is the "optimal partition of milk between calf and human consumption." Nonetheless, to increase milk offtake in traditional systems, cows are generally partially milked throughout the whole lactation. Under this practice, cows suckle their calves for a few minutes to stimulate milk ejection before milking, and then the calves can suckle the residual milk, which can range from 15 to 29 % of the milk produced (Ugarte 1991; Msanga and Bryant 2004), for a period between 15 min and 1 h (Tesorero et al. 2001). To further stimulate milk let-down during milking, the calf is generally tethered beside the cow (Combellas and Tesorero 2003). This practice, called restricted suckling, is increasingly common in many tropical countries (Fröberg et al. 2007). Restricted suckling of zebu cows and their crossbreeds has a positive effect on milk yield and consequently on the offtake for human consumption (Mejia et al. 1998; Coulibaly and Nialibouly 1998; Jenet et al. 2004; Fröberg et al. 2007; Sidibé-Anago et al. 2008). The production of milk rises because of the higher degree of udder emptying by the calf, which stimulates milk production (Wilde and Peaker 1990). On the other hand, restricted suckling results in a lower calf weight gain (Coulibaly and Nialibouly 1998), probably due to the lower milk intake (Mejia et al. 1998; Margerison et al. 2003).

Restricted suckling is replacing other calf rearing methods such as ad libitum suckling and artificial rearing in many tropical regions (Das et al. 2001). Compared to artificial rearing, restricted suckling increases milk yield (Magana et al. 1996; Coulibaly and Nialibouly 1998; Yilma et al. 2006), saleable milk (Sanh et al. 1995; Fröberg 2008), calf growth rate (Little et al. 1991; Sanh et al. 1995; Das et al. 1999; Yilma et al. 2006), health of dam and calf (Sanh et al. 1995) and calf welfare (Krohn 2001), while reducing stress (Hernández et al. 2006), mortality (Das et al. 1999), labour costs, milk handling (Tegegne et al. 1994) and abnormal suckling (Fröberg et al. 2007). On pasture, calves with restricted suckling are more active and sociable and graze more than artificially reared calves (Das et al. 1999; Fröberg et al. 2007). Restricted suckling

calves have a better milk conversion per unit weight gain of artificially reared calves (Sanh et al. 1995).

In tropical conditions, one of the major infertility problems of zebu cattle and their crossbreeds is the long anestrous period (>150 days), which imposes economic constraints on the efficiency of traditional cattle systems due to the longer intercalving interval (Vaccaro 1990). Suckling and nutrition were found to be the principal causes to lesser reproductive efficiency (Randel 1990). Restricted suckling, compared to unrestricted suckling, reduces the duration of the interval between calving and the first oestrus (Williams 1990; Ruas et al. 1991; Tegegne et al. 1992; Cázares et al. 1993). An investigation by Gallegos-Sanchez et al. (1990) concluded that, in restricted suckling systems, delaying suckling after milking improves reproductive performance by reducing the anoestrous period. Further, once-daily suckling rather than twice-daily suckling improves reproduction (Browning et al. 1994).

The milk obtained from restricted suckling, when the calf suckles the residual milk, has a lower fat content than whole milk (Sandoval-Castro et al. 2000; Tesorero et al. 2001; Yilma et al. 2006). The reason is that the fat content increases during milking: it can vary from 1 % in the milk drawn first to 10 % in the last (Syrstad 1993). The fat content variation in milk will benefit the calf weight gain when left suckling the residual milk but will result in a lower fat content in the milk for human consumption (Tesorero et al. 2001).

In traditionally managed cattle herds, cows are milked either once or twice a day (Agyemang et al. 1991). Copious studies (Agyemang et al. 1991; Sandoval-Castro et al. 2000; De Las Heras-Torres et al. 2008) have documented that reducing milk extraction for human consumption increases weaning weight while it decreases the total milk yield. In a study conducted by Agyemang et al. in 1988, the calves of dams milked once a day, rather than twice a day, had a 30 % higher growth rate. Sandoval-Castro et al. (1999), after testing four milking and suckling regimes, concluded that milking a cow twice a day and allowing the calf to suckle once a day resulted in the highest output of milk for human consumption. On the other hand, to improve calf growth, the cow had to be milked once a day in the morning and the calf had to suckle once a day in the afternoon. Delaying the suckling time after milking increases the milk consumption by the calf since the milk secretion after milking is more intense. In turn, there will be a lower milk output in the successive milking (Ugarte 1991). With regard to increasing saleable milk, Sandoval-Castro et al. (1999) confirmed the results of an earlier study by Teeluck et al. (1981). The latter authors also concluded that by this method the dam was maintained in better body conditions and the labour costs were reduced. Cows suckled ad libitum or milked once a day lose more body weight post-partum than dams milked twice a day (Agyemang et al. 1991). In traditional systems in the tropics, some producers decide not to milk one or two of the udder quarters during the first months of life of the calf (Okantah 1992).

Colostrum

High early milk extraction for human consumption may result in an insufficient ingestion of colostrum by the calf. The consumption of colostrum during the first 24 h of life is important to calf survival, welfare and health (Godden 2008). The first milk is an indispensable source of highly digestible energy and protein; it activates the digestive enzyme systems in the gastrointestinal tract and initiates the movement of the meconium along the intestines (Stull and Reynolds 2008). Furthermore, colostrum provides immunoglobulins, which are necessary for disease prevention; calves are born aggammaglobulinemic (Godden 2008; Nagalakshmi 2009). Compared to whole milk, colostrum includes higher levels of protein, immunoglobulins, non-protein nitrogen, fat, ash, vitamins and minerals (Quigley and Drewry 1998). Giving the new born calf a sufficient amount of colostrum is widely considered as a prerequisite to calf survival, performance and health (Godden 2008; Indira 2012).

Milk replacers and supplemental feeding

The rumen is not fully functional for the first weeks of life of the calf. During this period, farmers could decide to use milk replacers to feed their calves in order to use the milk produced by the dam for human consumption (Ouologuem et al. 1994). Feeding calves on milk substitutes, though, is rarely practiced and economical in the tropics particularly because of the limited availability of the ingredients for its preparation (FAO 2011a).

The use of supplementary feeds for calves instead is a method which has given positive results and that can be useful to obtain a higher milk offtake and an early weaning while improving calf growth. Research in traditional cattle systems in Mali by Ouologuem et al. (1994) showed that calves supplemented with concentrates, produced from locally available by-products, gained twice the weight of non-supplemented calves and that their dams gave more saleable milk. The relative profitability, even without considering the higher possible revenues from the sale of heavier calves, was higher in the supplemented group. A similar study conducted by Coppock and Sovani (1999), where calves were supplemented with legume hay and water for 10 months, showed that supplemented animals had higher growth rates and weaning weights than non-supplemented calves. Nonetheless, when the animals got to 3.5 years of age, the compensatory growth had equalised the weights.

Weaning age

In a research conducted by Sidibé-Anago et al. (2008), zebu dams suckling their calves for 5 months produced more milk for human consumption and had higher milk yields than cows suckled for 3 or 4 months. This management strategy did not influence calf growth rate when calves were supplemented. If calves are allowed to suckle for a longer period, the calving interval will be longer but the fertility rate will rise. As a result, the reproductive efficiency will be almost unvaried. Besides, early weaning of calves in the tropics was found not to benefit the amount of saleable milk due to the missed stimulus of suckling on milk let-down (Ryle and Orskov 1990). If the calf stimulates the dam through suckling for a longer period, 6 months, the lactation length is extended (Orihuela 1990; Ugarte 1991). Weaning age per se in partial suckling systems has a minor influence on live weight of calves (Ugarte 1991; Msanga and Bryant 2004).

Genetic resources

The genetic resources in traditional cattle systems may vary greatly, but typically these are based on *B. indicus* (Zebu) breeds or on crossbreeds between *B. indicus* and *Bos taurus* breeds (Simmental, Holstein, Charolais and Brown Swiss). Zebu cows have lower milk yields and shorter lactation lengths than crossbred cows (Syrstad 1993; Das et al. 1999), and crossbreeding is useful to combine the improved production traits of European breeds with the ability to resist to heat stress, morbidity, and poor feed, and management of indigenous cattle (Gradiz et al. 2009). When milk is considered as the primary output, Zebu cattle are crossed with a dairy breed such as Holstein. On the other hand, if beef production is emphasised over milk production, well-adapted local dual-purpose cattle are crossed with specialised beef breeds (Peel et al. 2010). Holmann et al. (2003) concluded that crossbred cattle with low and medium levels of dairy genes are the most economically viable breed groups for dual-purpose cattle systems in Colombia. Indiscriminate cattle crossbreeding, though, may contribute to genetic erosion (FAO 2007).

Conclusion

Specialised beef and milk production systems are not feasible for most producers in the tropics. Traditional systems, like dual-purpose systems in Latin America and pastoralist systems in Africa, are better suited to resource-poor and to the conditions that prevail in the tropics. It is clear from the literature reviewed that milk is a very important product for traditional households, especially pastoralists in Africa, in terms of animal protein and energy. Besides, the regular income from milk sales is important to sustain the livelihoods of traditional cattle keepers and their families and is an opportunity for women to become part of the economic activity. Milk money is particularly relevant for the poorest producers; it will help the herder pay for the everyday expenses.

The available literature shows that milk, in terms of economic, social and subsistence value, is more valuable than meat. Therefore, under the conditions that characterise traditional cattle systems in the tropics, it is appropriate to have a higher milk offtake at the expense of calf growth.

There are various socio-economic aspects which influence milk allocation in traditional cattle systems. The herders, who are close to markets with good milk prices, will have a higher milk offtake to the detriment of the calf. Moreover, there is a relationship between income levels and milk offtake. The share of milk extracted for human use is more for the poorer households and less for the wealthier households, as the former have a higher need of milk for subsistence and income generation. Better-off households invest more milk in calf growth. In some pastoralist societies, milk is not sold due to its social value.

Productivity growth is crucial to economic growth. In order to have higher milk production, traditional cattle keepers should cross local dual-purpose cattle breeds with specialised dairy breeds. Female calves should be better cared for than male calves because of their value as future reproductive and productive stock. Nonetheless, all calves have to be kept alive for inducement of milk let-down. Restricted suckling, compared to other calf feeding methods such as ad libitum suckling and artificial rearing, is the best practice to achieve this end while obtaining more saleable milk throughout the lactation period. Restricted suckling has to be managed appropriately in order to increase milk offtake. The calf should be allowed to suckle after milking so that it will feed on the residual milk which cannot be milked for human consumption and has a higher fat content. To have a higher offtake of milk for human consumption, the cow should be milked twice a day and the calf should be allowed to suckle once a day. Adequate colostrum intake is essential for calf health and survival. When feasible, the use of supplementary feeding is recommendable in order to have a higher milk offtake and an early weaning without affecting the health of the calf.

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