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Animal Health and Productivity Among Dairy Cattle in Bihar, India

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Animal Health and Productivity Among Dairy Cattle in Bihar, India

Djurhälsa och produktivitet hos mjölkkor i Bihar, Indien

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SUMMARY

Bihar lies in the north of India and is one of the poorest states in the country. Agriculture is very important in the local economy and the contribution of animal husbandry, where dairy animals are the most common, is considerable. A majority of dairy farmers are poor smallholder, to whom milk production is important both as a source of additional income as well as being a source of important nutrients to the farmers family. Milk yield per animal in Bihar has however been low compared to the rest of the country because of problems with disease, reproduction and animal management. The aim for this study was to investigate general animal health and management in dairy cattle, to identify ways to improve the milk yield of animals to improve the situation of local farmers. Factors included and registered in the study were related to animal management and health, and included milk yield, body condition scoring (BCS) and feed, water intake and hoof health and lameness. Data was collected through clinical examinations of individual animals and through the use of a questionnaire. A total of 229 households and 342 individual animals were included in the study. Dominance of smallholders in Bihar was verified in the study, with a mean of 3.5 animals per household, and an absolute majority of the animals surveyed were crossbred. Mean daily milk yield per animal in households was 8.3 L/day. Body condition and rumen fill were both found to be within adequate ranges, indicating a satisfactory energy intake for animals. Both inclusion of concentrate in the feed of animals and increased intake of water was found to be associated with a significant increase in milk yield. Inclusion of concentrates in feed led to an increase of 1.78 L/day in mean daily milk yield, and for every additional liter of water, mean daily milk yield increased by 0.1 L/day. Hoof status of surveyed animals was found to be normal in an absolute majority of cases, and the annual incidence rate of lameness was found to be extremely low when compared to previous studies. In conclusion, adequate BCS, rumen fill and good hoof status indicates a good general health of animals in Bihar. The good hoof status and low incidence rate of lameness indicate that hoof related lesions are not a major problem in the state. Proportion of crossbred animals and the daily milk yield of animals seem to be higher as compared to previous studies from Bihar, and a potential of increased milk yield through an increase of water intake as well as from inclusion of concentrates in the feed is shown. Further research would however be needed to verify the results of this study.

SAMMANFATTNING

Bihar ligger i norra Indien och är en av de fattigaste delstaterna i landet. Jordbruket utgör en betydande del av den lokala ekonomin, där djurhållning, särskilt mjölkproduktion, är en viktig del. En majoritet av mjölkbönderna är fattiga och äger bara små arealer jordbruksmark. För dessa bönder utgör mjölkproduktionen både en möjlighet till ytterligare inkomster, och en källa till viktiga näringsämnen för familjen. Produktionen av mjölk per djur i Bihar har dock varit låg jämfört med resten av landet, på grund av problem med sjukdomar, reproduktion och djurhållning. Målet för den här studien var att undersöka den allmänna djurhälsan samt djurhållningen hos mjölkkor för att finna sätt att möjliggöra en ökad mjölkproduktion, för att förbättra situation för de lokala bönderna. Faktorer som inkluderades och registrerades i studien fokuserade på djurhållning och djurhälsa, och inkluderade mjölkproduktion, utfodring och bedömning av hullpoäng (body condition score, BCS) samt klövhälsa och hälta. Materialet samlades in genom klinisk undersökning av enskilda djur samt med hjälp av ett frågeformulär. Totalt 229 hushåll och 349 enskilda djur inkluderades i studien. En majoritet av bönderna var småbrukare vilket bekräftar resultat i tidigare studier, med ett genomsnitt på 3,5 djur per hushåll. En absolut majoritet av djuren som ingick i studien var av blandras. Den genomsnittliga dagliga mjölkproduktionen per djur på gårdarna var 8,3 L/dag. Hullpoäng och våmfyllnad bedömdes vara inom godtagbara intervall, vilket tyder på ett för djuren tillfredställande energiintag. Både inkludering av kraftfoder i fodergivan och ett ökat vattenintag var associerade med en signifikant ökning av mjölkproduktionen. Inkludering av kraftfoder medförde en ökning av den genomsnittliga dagliga mjölkproduktionen på 1,78 L/dag, medan den genomsnittliga dagliga mjölkproduktionen ökade med 0,1 L/dag för varje ytterligare liter vatten. Klövhälsan bedömdes vara god hos en absolut majoritet av djuren, och den årliga incidensen för hälta var extremt låg jämfört med andra studier. Sammanfattningsvis så tyder hullpoäng, våmfyllnad och klövhälsa på att den allmänna djurhälsan i Bihar är god, och den goda klövhälsan och den låga hältincidensen tyder på att klövlidanden inte utgör ett stort problem. Andelen djur av blandras och den dagliga mjölkproduktionen per djur är högre än i tidigare studier från Bihar. Inkludering av kraftfoder i fodergivan samt ökning av vattenintaget medförde ökningar av den dagliga mjölkproduktionen, vilket tyder på en potential för ökad mjölkproduktion. Vidare forskning krävs dock för att säkerställa resultaten i denna studie.

Contents

Introduction

Poor animal health and husbandry have been shown to be associated with considerable decreases in animal productivity and can therefore cause significant economic loss. In Bihar, a state in the northern part of India, livestock husbandry and milk production is dominated by poor smallholders and constitute an important part of local economy (Government of Bihar, 2014; Singh, 2013; Singh et al., 2010). Bihar is one of the poorest states in the country, with a per capita income that is estimated to be 65 % less than national average (Singh et al., 2013). Contributions of agriculture to state GDP in Bihar are 37 %, of which a considerable part, 38-45 %, is contributed by animal husbandry (Singh, 2013; Singh et al., 2010). This is higher than Indian national levels, where animal husbandry is estimated to contribute 27 % of the total agricultural GDP (Singh et al., 2010). Although a considerable increase in milk yield has been seen in the last few decades, average milk yield per animal and day in the state is still low and problems with disease, reproduction and husbandry are expected to cause considerable losses on total value of milk production in the state (Singh, 2013; Singh et al., 2010). Constraints in milk production are reported to include disease, resulting in decreased milk yield, inadequate amounts of feed, as well as feed of poor quality (Singh, 2013; Singh et al., 2010). Improvements in animal health and management resulting in an increased milk yield can be expected to benefit poor farmers economically, as well as resulting in an improved animal welfare.

Objectives

Selling milk produced by milking animals constitute an important source of income for many poor smallholders. An increased milk yield would therefore be expected to render an increased income for these smallholders. The aim of this study was therefore to survey the possibility of increasing milk yield through changes in animal management. In order to enable this, local conditions for milk production was investigated in order to identify constraints to milk production. Factors registered were related to animal management and health, and included milk yield, body condition scoring (BCS) and feed, water intake and hoof health and lameness. Factors to be included were chosen based on results in previous studies.

This project was conducted as part of a master thesis in veterinary medicine from the Swedish University of Agricultural Sciences. It was carried out as a part of the Minor Field Study (MFS)-programme that is organized by the Swedish governmental organization SIDA (Swedish International Development Agency).

LITERATURE REVIEW

Feed and Body Condition Scoring

India has had a continual shortage of feed and fodders, with ineffective feed quality control as well as feed of poor quality constituting major problems (Staal et al., 2008). India is therefore considered to have a significant potential of increased milk yield through the use of improved feeding, where better use of concentrate in the feed (Duncan et al., 2013) and usage of roughage of better quality (Patil & Udo, 1997) are considered to be essential parts. Usage of concentrate in the feed in India has been associated with more intense farming, with stall-feeding at the expense of grazing, as well as with proximity to well-developed market sites (Duncan et al., 2013). Improving and ensuring an effective infrastructure is therefore imperative for intensified dairy production.

Feed

Feed intake is commonly discussed in terms of dry matter intake (DMI), i.e. the intake of solids, dry matter (DM), in the feed. Increased DMI have been shown to be associated with an increase in milk yield (Allen, 2000; Auldist et al., 2016; Patel & Udo, 1997; Reid et al., 2015). A goal of feeding dairy cows is therefore to increase the total amount of DMI in order to try to maximize milk yield, e.g. through the use of concentrates (Reid et al., 2015). The effect of DMI on milk yield is further demonstrated by the fact that cows with restricted amounts of feed have been shown to have reduced milk yields (Gabbi et al., 2016). The reduction of DMI caused by the restriction is compensated by a combination of decreased milk yields and by a mobilization of body reserves (Gabbi et al., 2016). In cases of severe restrictions of feed intake, effects can also be seen on the composition of the milk (Gabbi et al., 2016).

Studies have shown that milk yield is increased when lactating animals are provided with mixed rations as compared to being provided the same kinds of feed separately (Auldist et al., 2016; Istasse et al., 1986). This is probably the result of higher DMI as well as a higher digestibility for feeds that were processed in this way (Istasse et al., 1986). Seeing however that animals fed mixes with low amounts of concentrates demonstrated no significant effects on either milk yield or feed digestibility, this effects seems to be present only if the mix contains levels of concentrates that are high enough (Istasse et al., 1986). Furthermore, some studies have suggested that inclusion of certain types of feed ingredients may affect milk yield. Inclusion of canola meal in the feed of lactating animals have for example in some studies been implied to result in slight increases in milk yield (Auldist et al., 2016).

Intake of DMI is determined by the physical as well as the chemical characteristics of the feed, e.g. fiber content, fiber and starch digestibility and particle size (Allen, 2000). Further, palatability of the feed has also been found to be very important in feed intake in ruminants (Albright, 1992). In high producing cows and cows fed diets with high amounts of forage, DMI is often limited by the physical limitations associated with distension of the reticulo-rumen as well or of the gastrointestinal tract as well as by the time required to masticate (Allen, 2000).

As demonstrated by Patil & Udo (1997), the breed of an animal is one of the major factors affecting DMI and the resulting milk yield. Comparisons of some indigenous Indian breeds of cattle with Holstein-/Jersey-crossbreeds showed that crossbreeds consumed significantly more both roughage (dry and green fodder) and concentrates (1.2 and 1.4 times higher, respectively), resulting in a significantly higher DMI. Parts of this increase is probably explained by the fact that farmers with crossbred cows were possibly more inclined to try and match the needs of the animal with the feed.

The goal for supplementing feed with concentrates is to increase total DMI (Reid et al., 2015). Lactating animals receiving concentrates have been shown to have significantly higher milk yield when compared to groups not receiving concentrates (Muraguri et al., 2004; Reid et al., 2015). It has also been demonstrated that lactating animals receiving higher amounts of concentrates show significantly higher milk yields when compared to animals receiving lower amounts (Auldist et al., 2016; Istasse et al., 1986; Patil & Udo, 1997), although the increase of DMI caused by the intake of concentrates seems to have to pass a certain level to be sufficient to increase milk yield (Spiekers et al., 1991). Although other studies fail to show a significant increase of milk yield in response to increasing amounts of concentrates, they show a positive trend favoring higher amounts of concentrate in the feed (Allhassan & Owusu, 1980; Keady et al., 2001).

While use of concentrates lead to a significantly increased total DMI, the proportion of roughage DMI decreases significantly when supplementing with concentrates (Keady et al., 2001). This is due to the fact that concentrates have a lower fill value, i.e. the volume of feed per kg of DM is lower for concentrates compared to that of dry and green fodder, which enables the increase of total DMI (Reid et al., 2015). This is further demonstrated as the inclusion of roughage in the feed has been shown to have a significant but small negative effect on milk yield (Patil & Udo, 1997).

Even though increased amounts of concentrate lead to increased milk yield, the efficiency of utilization decreases markedly with increased DMI (Spiekers et al., 1991). The most efficient usage of concentrate feeding therefore seems to be low-grade usage of concentrates combined with forage of adequate quality, which was shown to ensure economic returns (Alhassan & Owusu, 1980). When increasing the amount of concentrates further the excess energy supplied that is not used for increased milk yields seems to be used to build up body reserves (Keady et al., 2001).

Rumen Filling

Rumen fill scoring (RFS) is an indirect subjective measurement of feed intake (DMI), but also of feed composition as well as of digestion and passage rate (Burfeind et al., 2010; Kawashima et al., 2016; Zaaijer & Noordhuizen, 2003). Assessment of RFS is made through observation of the rumen fossa, which is demarcated by the last rib, the transverse processes of the lumbar vertebrae and the hook bone on the left side of the animal. A score of 1-5 is given, where 1 signifies a very marked rumen fossa and an empty rumen, and 5 that the rumen is well filled and that the fossa is not visible (Zaaijer & Noordhuizen, 2003). All scores except 1 can be considered normal depending on which stage of lactation the assessed animal is in. Through the indirect assessment of feed intake, RFS can be used to assess the energy status of animals (Kawashima et al., 2016). Scoring using RFS has significant both intra- and inter-observer repeatability, and changes of RFS are correlated with changes in DMI (Burfeind et al., 2010).

Body Condition Scoring

Body condition scoring (BCS) is a subjective method to assess the storage of metabolizable energy in the muscle and fat tissues of individual live dairy cows (Edmonson et al., 1989; Wildman et al., 1982). It is therefore an indirect measurement of the balance between energy intake and energy expenses. Mean body condition may differ between animals in different stages of the lactation (Wildman et al., 1982), because of the varying energy requirements in the different stages. According to Roche et al. (2009), BCS might also be used as a valid indicator of animal welfare.

There are a few different BCS-scoring systems used in practice and in research today, differing in type of assessment, with visual assessment or a combination of visual and physical assessment, and in the range of the scoring system, including 5-, 8- and 10-point BCS-scales (Roche et al. 2004). The lowest scores are used for animals that are emaciated while the highest are given to obese animals (Roche et al., 2009). A study by Roche et al. (2004) showed a strong correlation between different scoring systems, but also concluded that correlation was weaker with BCS-scorings based solely on visual assessments.

According to literature, the body condition of a cow at calving appears to be very influential for the lactation that follows. Roche et al. (2009) showed that the body condition at calving is likely the most important factor during the lactation, as it affects the milk yield, dry matter intake, the loss of body condition post calving as well as the cow’s immunity during the early stages of lactation. In another study, Roche et al. (2007) also demonstrated that body condition at calving in combination with the loss of body condition during the first period of the lactation has a significant effect on the milk yield.

There are multiple studies that state that increased body condition at calving has a positive effect on the milk yield of the subsequent lactation (Domecq et al., 1997; Grainger et al., 1982; Waltner et al., 1993). It has also been demonstrated that body condition at calving has short term (1-5 weeks of lactation) as well as long term (6-20 weeks of lactation) effects on the milk yield in the following lactation (Grainger et al., 1982). The positive effect of body condition at calving on the milk yield in the subsequent lactation, as explained by Grainger et al. (1982) as well as Waltner et al. (1993), is thought to be due to the fact that the increased storage of subcutaneous fat allows the body to maximize the partitioning of energy into milk yield while ensuring the health of the animal at the cost of decreasing body condition during early lactation. The positive effect of body condition at calving on milk yield seems to have its limits though, as cows that are over-conditioned at calving are more likely to have reduced milk yield, be in milk fewer days, as well as being more likely to be affected by metabolic disorders around parturition (Roche et al, 2009).

According to a study by Waltner et al. (1993) the milk yield increased with 322 kg during the first 90 days of the lactation if body condition was increased from BCS 2 to 3. If the body condition was increased from BCS 3 to 4, an additional increase of 33 kg in milk yield could be seen during the same period. When body condition was increased from BCS 4 to 5 on the other hand, the milk yield during the first 90 days of the lactation decreased with 223 kg. According to Roche et al. (2007) and Roche et al. (2009) the optimal body condition at calving for maximal milk yield is BCS 3.5 on the 5-point scale, although the increase of milk yield is only slight after body condition passes BCS 3.0. A BCS-score lower than 3.0 at calving may on the other hand result in reduced milk yield (Roche et al., 2009).

Other studies could not find any connection between body condition at calving and milk production. Jílek et al. (2008) could not demonstrate any relationship between these two factors in the first 5 months of lactation, and Ruegg & Milton (1995) concluded that neither peak lactation nor total milk yield during the lactation as a whole was affected by body condition at calving.

Body condition decreases quite rapidly during early lactation (Domecq et al., 1997), and reaches nadir after a few weeks, around the time for the maximum milk yield (Domecq et al., 1997; Wildman et al., 1982). During this time the nutrition and management of the individual cow has little effect on the ongoing loss of body condition (Roche et al., 2009). In a study by Jílek et al. (2008), cows that had a body condition lower than BCS 3.5 (scale of 1-5) in the first month of lactation were shown to have the highest level of milk yield during the first 5 months amongst the animals being studied. According to the authors this could be caused by a higher mobilization of the fat deposits in these animals. In the same study, cows that showed the lowest body condition during the first month of the lactation continued to have the lowest BCS-score throughout the next four months (Jílek et al., 2008). In a study by Wildman et al. (1982) it was demonstrated that cows that did not show significant change in body condition during the lactation were more efficient milk producers but with a shorter duration of the lactation. In over-conditioned cows the loss of condition during the first weeks of lactation appears to be greater compared to cows of normal condition (Grainger et al., 1982), while at the same time appearing to be less efficient at producing milk (Wildman et al., 1982). Individual cows whose body condition increased significantly during the lactation also have been shown to be less efficient milk producers, while also showing a higher BCS-scoring at the end of lactation (Wildman et al., 1982). After peak lactation the body condition normally starts to increase again, and then usually continues to increase throughout the lactation (Waltner et al., 1993; Wildman et al., 1982).

The body condition during dry-off has been suggested to affect the milk yield in the following lactation. Results of a study conducted by Domecq et al. (1997) suggested that cows that increase their body condition during dry-off attain a higher milk yield in the first 120 days of the coming lactation. In their study, individual cows that increased their BCS by one point during dry-off produced 545.5 kg more milk during the first 120 days of the lactation, while cows with additional increases of BCS showed decreased milk yield. In contrast, Gearhart et al. (1990) showed that modifying body condition during dry-off might result in increased risk for reproductive problems in individual cows. Gearhart et al. (1990) also suggested that over-conditioned individuals were subject to increased risk of lameness as well as reproductive problems during their next lactation.

Water, Water Supply and Milk Production

Many factors have been shown to be able to influence water intake in individual cows, including dietary factors, parity and calving, the current body weight of the animal, health, as well as environmental factors. In a study by Meyer et al (2004) it was shown that increasing the amount of roughage in the diet was associated with a decrease of water intake, while an increased intake of the electrolytes Na^+ and K^+ lead to an increased intake of water (Meyer et al., 2004). According to NRC (2001) a slight effect of the temperature of drinking water on water intake has also been indicated by some studies.

Dietary factors such as the composition of the diet (Cardot et al., 2008) and the dry matter intake (DMI) (Cardot et al., 2008; Kume et al., 2010; Meyer et al., 2004; NRC, 2001) have both been shown in studies to affect the water intake. A study conducted by Kume et al. (2010) showed a strong correlation between dietary DM and the water intake by drinking and/or through food intake, while only a weak correlation could be found between dietary DM and total water intake. In contrast, the same study showed that the DMI of dry cows was correlated with the total water intake, but not with the water intake through drinking.

In a study by Lukas et al. (2008) the period around parturition as well as primiparity was associated with a decreased intake of both water and DM. Another study conducted by Meyer et al. (2004) showed a positive correlation between parity and water intake, while also showing that the body weight of an animal was positively related to the water. In contrast to this, a study by Andersson (1987) failed to show any significant effect of live weight on the water intake of animals.

The health of an animal can also have an effect on the water intake. Lukas et al. (2008) showed a negative association between both fever and hoof treatment on the water intake of animals. The same study also concluded that what was defined as other health events (including ketosis, milk fever, and antibiotic treatments) correlated with decreased DMI as well as water intake.

In a review article, Kadzere et al. (2002) concluded that heat stress was correlated with an increase in water intake. Meyer et al. (2004) showed that water intake by average increased by 1.52 kg/day when the ambient temperature was increased by 1°C, while a study by Andersson (1987) showed that an increase of 1°C resulted in an increased water intake of 1.1 L/day. In contrast to these studies Lukas et al. (2008) failed to show a significant correlation between ambient temperature and water intake. Increases of relative humidity have been shown in studies to be negatively correlated with water intake (Lukas et al., 2008; Meyer et al., 2004).

Multiple studies have found a significant correlation between water intake and milk yield (Andersson, 1987; Cardot et al., 2008; Kadzere et al., 2002; Kume et al., 2010; Meyer et al., 2004; Steiger Burgos et al., 2001). In a study by Meyer et al. (2004) it was shown that for each additional kg of milk produced the amount of water drunk by the cow is increased with 1.3 kg. Restricting the water of a group of cows lead to decreased milk yields, but apart from higher contents of lactose and urea no significant changes could be shown in the composition of the milk (Steiger Burgos et al., 2001). King & Stockdale (1981) showed that the milk yield as well as the live weight of a group of cows given restricted access to water only once daily showed a significantly reduced milk yield for the first four days of the period, After these first few days however, the milk yield returned to normal. The study by King & Stockdale did however fail to show a significant correlation between water intake and milk yield during the lactation as a whole in any of the groups included in the experiment (free access to water, water only given for 20 min prior to milking, water given once for 20 min prior to evening milking only). In an experiment looking at how different water flow rates effected milk yield, higher flow rates were shown to result in a slight but non-significant increase in milk yield (Andersson et al. 1984).

According to studies, the peaks of water intake occur after feeding (Andersson, 1987; Cardot et al., 2008) and milking (Cardot et al., 2008). Results in the study by Cardot et al. (2008) also showed that a majority of water intake through drinking occurs during daylight hours (about 75 % between 6 am to 7 pm). In a study by Willms et al. (2002), cows getting access to clean water were shown to spend more time grazing and less time resting compared to other groups of animals that were supplied with water of inferior quality. The authors suggested that this was due to the higher palatability of the cleaner water, leading to higher water and feed intake.

Hoof Health and Milk Production

Lameness in cattle is often associated with considerable pain and constitutes a problem to both welfare and productivity (Alban et al., 1996). Lesions in the hooves will cause stress as well as pain, leading to increased levels of adrenaline. This will result in a reduced milk yield, as well as causing decreased mobility for the animal resulting in decreased feed intake (Singh et al., 2011). The impact on the individual animal depends on both the duration and the severity of the condition (Alban et al., 1996). Risk of lameness is also influenced by individual factors such as parity (Rajala-Schultz et al., 1999), stage of lactation (Green et al., 2002) as well as husbandry factors such as housing and feeding (Onyiro et al., 2008).

A majority of studies looking at the association between lameness and milk yield conclude that higher than average milk yield is associated with lameness. High yielding cows have been shown to be more likely to be affected by lameness, either in general (Barkema et al., 1994; Dooho & Martin (1983); Green et al., 2002; Onyiro et al., 2008), or by specific causes of lameness, such as foot rot (Alban et al., 1996), hock lesions (Alban et al., 1996; Sogstad et al., 2007), lameness caused by lesions in the interdigital cleft (Rowlands & Lucey, 1986), sole ulcers (Barkema et al., 1994; Hultgren et al., 2004; Rowlands & Lucey, 1986), lesions in the white line sites of the claw (Rowlands & Lucey, 1986; Sogstad et al., 2007) as well as heel-horn lesions (Sogstad et al., 2007). According to a review by Fourichon et al. (1998), almost all of the included studies accounted for an increased risk of lameness in high yielding cows

When affected by lameness however, milk yield of affected animals is usually decreased. Some studies state that lameness in general brings about decreased milk yield (Enting et al., 1997; Green et al., 2002; Onyiro et al., 2008; Rajala-Schultz et al., 1999; Warnick et al., 2001) while others state that decreased milk yield is only brought about by specific causes of lameness such as heel lesions (Rowlands & Lucey, 1986) or hock lesions (Barielle et al., 2003). Warnick et al. (2001) state that even though all forms of lameness cause decreased milk yield, some causes such as foot abscesses were shown to result in a greater loss of milk yield. However, in a study by Barkerna et al. (1994) it is stated that apart from sole ulcers (that are shown to be associated with an increased milk yield) other causes of lameness are in fact not associated with either higher or lower milk yields. In a review by Fourichon et al. (1998) about half of the included studies associated lameness with a decreased milk yield. Fourichon et al. (1998) concluded that lameness results in moderate short-term losses, with a reduced milk yield of from 1.3-2.0 kg/day during the first month to from 0.3-0.4 kg/day for the rest of the lactation.

Lameness and hoof lesions in dairy cattle in India are not well described in literature. According to one study the lameness incidence rate was 38 cases of lameness/100 cow-years in the state of Haryana in northwestern India (Singh et al., 2011). According to another study, clinical lameness in Indian dairy cattle is caused by sole ulcers and white line fissures, while other types of lesions did not cause clinical lameness (Zahid et al., 2014). Most cases of lameness are observed in lactating cattle and is most commonly seen in the first month post-partum, followed by lameness in the second month post-partum as well as lameness prior to calving (Singh et al., 2011). Incidence of lameness was higher in cows having calved during winter, followed by cases during fall, then by cases during rainy and summer seasons (Singh et al., 2011).

MATERIAL AND METHOD

Study Design

This project was part of a joint project led by the International Livestock Research Institute (ILRI) with the objectives to better characterize dairy production, diseases and other limitations to the productivity in the state of Bihar in India. Information was sought through the use of a questionnaire completed with help of local interpreters as well as assessments of individual animals regarding clinical parameters including body condition score (BCS) and hoof status. Clinical samples of blood as well as of milk were also collected from the animals included in the study to enable for screening for certain important diseases, including brucellosis, leptospirosis and mastitis. None of the results of the tests performed using these clinical samples are included in this study but will be published elsewhere.

Study Area

Bihar is a state in the northern part of India and is considered to be one of the poorest and most underdeveloped states in India (Government of Bihar, 2014; Singh, 2013). 90 % of the population in Bihar lives in the rural parts of the state where many people are dependent on agriculture for their livelihood (Government of Bihar, 2014). Animal husbandry is dominated by poor smallholders (Singh, 2013), and many people keep animals to supplement their low income (Government of Bihar, 2014).

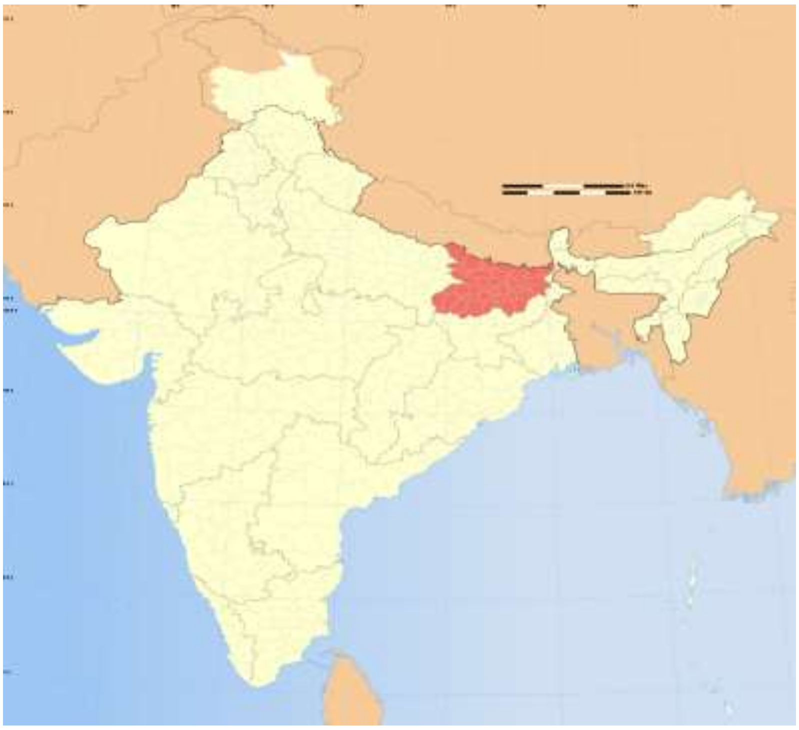

Figure 1 - Map of Bihar

Source: PlaneMad/Wikimedia

The administrative centre and capital city of the state is Patna, situated in central Bihar on the southern shore of river Ganges. The climate of Bihar is diverse but is generally subtropical. Temperature in the state varies between a maximum of around 44°C in summer down to a minimum of around 5°C in winter. The study was conducted between the 7th September and the 30th of October. During this period maximum daily temperatures varied between about 25-38°C while minimum daily temperatures varied between about 17-25°C.

To conduct this study, three districts were selected in the state of Bihar. Patna, being the main city of the state, was included as one of these districts for convenience and to allow for use of local laboratories with adequate resources. The other two districts where sampling was planned to be conducted, Gaya and Nalanda, were selected prior to the start of the study to be representative of other districts. Gaya was later excluded due to problems with getting the support of local veterinary personal in conducting the sampling in the area, which was expected to make sampling hard and inefficient. To replace Gaya, the area of Vaishali was included. Vaishali was selected due to convenience, since the exclusion of Gaya happened when the sampling had already been initialized.

The selected districts were further divided into urban and rural blocks. In Patna a peri-urban block was also included, given a total of 7 areas where sampling would be conducted. In each of these areas 4 villages were planned to be selected to be the subjects of sampling. These villages were selected for convenience with help of local veterinary personnel, based on personal contacts of local veterinary personnel in the villages. This approach was chosen to improve participation of local farmers in the study.

Study Animals

From each of the selected villages the aim was to include between 8-12 households. From each household up to three animals were then selected to be included in the study. If fewer than three eligible animals were present on the farm, all eligible animals were to be sampled. In case there were more than three animals considered eligible on the farm, animals included in the study were to be randomly selected.

Problems however emerged with getting farmers to giving their consent to allowing multiple animals to be included in the study. Therefore often less than three animals were included even in households where there were in fact three or more eligible animals present. The selection of which animals to include was also often not randomized as the selection required the consent of the farmer.

According to the original plan of this study buffaloes were to be included. At the end of the study however, very few buffaloes had been surveyed. Data from buffaloes were therefore excluded from the study.

Questionnaire

The questionnaire included questions about prevalence of disease, the animal husbandry and general practices on the farm as well as some personal information about the farmer, including age, educational qualifications and total number of family members. Data was recorded on farm level and questions included in the questionnaire included the mean amount of water given to individual lactating cows daily (in liters), types of feed supplied, number of times a day the animals were fed, if any preventive hoof care was conducted and average amount of milk produced/sold per day (in liters) for the whole farm. Milk produced daily at the farm was then normalized by dividing with the number of lactating cows to yield a mean of milk produced per cow within each farm. Questions regarding types of feed supplied were answered yes or no, and types of feed included in the question were dry fodder, concentrate and green fodder. The questionnaire was completed with the help of local interpreters who posed the questions to the farmers and then filled in the answer.

Individual Animal Data

The individual animal data included general information as well as assessments of certain clinical aspects of the individual animals included in the study. General information included amongst other breed, age, parity, reproductive status and the stage of lactation of the animals. This information was completed by the farmers with the help of the local interpreters. Assessed clinical aspects included BCS (5-point scale), rumen fill (5-point scale) and length, form and status of hooves. Assessments of BCS were made based on observation check lists presented in previously published studies. Assessments of hoof status were made based on an observation checklist used previously in an unpublished study. Based on this checklist visual

Figure 2 - Abstract of the hoof assessment checklist used in the study

assessments were made of toe length as well as of the form of the hoof. Hoofs of animals were scored between 1 to 4, 1 being hooves of normal length and shape, and 4 being hooves with severely changed length and shape (see Figure 1 for further information).

The assessments were performed by the author as well as by two other students of veterinary medicine from the Swedish University of Agricultural Sciences. To consolidate similar assessments, the initial assessments of the project were performed by all three evaluators individually and were followed by discussions of these individual assessments. For the majority of the project however the assessment of individual animals was performed solely by one individual.

Statistical Analysis

Because of an insufficient sample size all buffaloes were excluded from analysis of data in this study. Farm data from farms with buffalos were also excluded. When looking at individual animal data, cattle from all households were included in the results.

Data on daily milk yield was collected in form of daily average milk yield of the entire farm as estimated by the farmer. No data on the daily milk yield of individual animals was collected. The total daily milk yield of the farm was then related to the number of milking animals at that time, resulting in a mean milk yield per individual milking animal on each farm. Cattle on farms that also had buffaloes were excluded due to the major divergence between expected average milk yield between the species. As the specific density of cow's milk is 1.02-1.05 kg/L (FAO, 2012), L/day and kg/day will be used synonymously when comparing the results from this study with those of other studies.

All analyses were done at farm level, using farm level water intake per cow, and mean daily milk yield per cow on the farm. Based on results from the data collection, mean as well as minimum and maximum values were calculated of mean water intake per animal on the farm and of the mean daily milk yield per animal on the farm respectively. An incidence rate of lameness was calculated based on questionnaire results. Data collected on water intake and inclusion of different types of feed were also analyzed for association with daily milk yield. Association between water intake and milk yield were analyzed with simple linear regression, while the effects of inclusion of different types of feed on milk yield were analyzed with 2-sample T-tests.

RESULTS

General Animal Data

A total of 229 households and 342 individual animals, out of which 313 were cattle and 29 were buffalos, were surveyed in this study. Mean number of animals per household (including buffaloes) was 3.5 (range 1-35 animals). 91 % of households had fully stall fed herds, while the remaining 9 % had partly stall fed herds.

312 of the included cattle had individual data on breed (see Table 1 for distribution). In one individual data on breed was missing, wherefore this individual was not included when calculating percentages of breeds. 305 (97.8 %) of the sample cattle were crossbreed. Out of the remaining 7 animals most were of indigenous breeds.

Table 1 - Distribution of breeds amongst surveyed animals in Bihar, India.

Breed	Number of animals (Total n=312)	Percentage
Crossbreed (Unspecified)	305	97.8 %
Indigenous (Unspecified)	4	1.3 %
Jersey	1	0.3 %
Red Sindhi	1	0.3 %
Sahiwal	1	0.3 %

Milk Yield

181 farms were included in calculation of mean milk yield per animal and day. The mean value per farm was 8.3 L/cow/day, with values ranging from 1.00-30.00 L/day (see Figure 3). Lactation number of included animals ranged from 0 to 15 with a mean of 2.3 lactations.

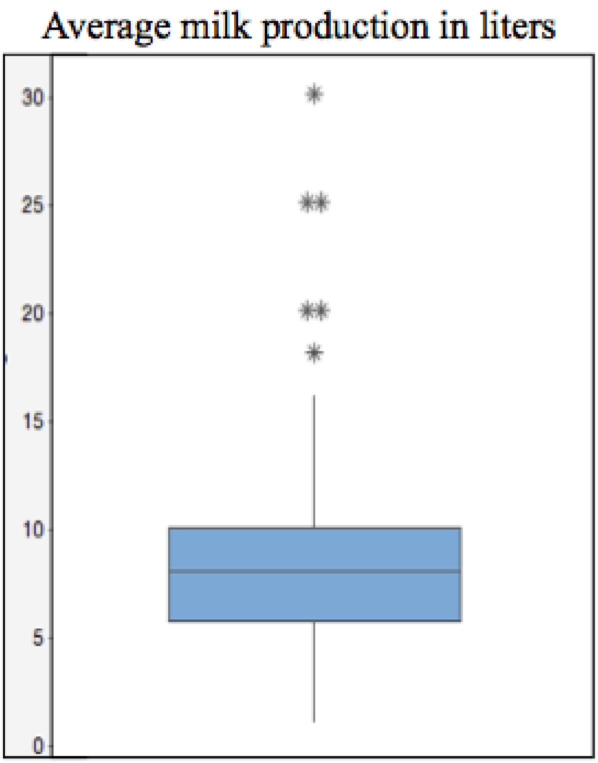

Figure 3 – Boxplot of mean daily milk yield per milking animal in surveyed households in Bihar, India.

Body Condition Scoring

Scoring of body condition was performed on a total of 306 individual cattle (see Table 2). Values ranged from 1 to 4 (no individuals were scored 5).

Table 2. Body condition scoring of surveyed dairy cattle according to a 5-grade scale in Bihar, India.

Body condition score	Number of animals (Total n=306)	Percentage
1	3	1.0 %
2	77	25.1 %
3	197	64.4 %
4	29	9.5 %
5	0	0.0 %

Feed and Rumen Filling

98 % of households fed animals two times per day. Of these households, 97 %, 72 % and 83 % included dry fodder, green fodder and concentrate respectively in the feed of animals. Inclusion of concentrate in the feed of animals was found to be significantly positively correlated with milk yield (P = 0.0050), with a difference of 1.78 L/day and a 95 % confidence interval of between 0.55 and 2.99 L/day. Inclusion of other investigated feed items (dry fodder, green fodder) in the feed was not found to be correlated with milk yield (P = >0.05). Analysis was made on data from a total of 181 households.

Out of all animals 75.8 % were judged to have a normal rumen fill (3). 12.1 % and 11.3 % were assessed to have a rumen fill score of 2 or 4 respectively (see Table 3).

Table 3. Rumen fill scoring scoring of surveyed dairy cattle according to a 5-grade scale in Bihar, India.

Rumen filling score	Number of animals (Total n=265)	Percentage
1	2	0.8 %
2	32	12.1 %
3	201	75.8 %
4	30	11.3 %
5	0	0.0 %

Water Intake

In total, 181 farms were surveyed for average water intake. Mean water intake per lactating animal and day on farms was 35.29 L/day, with values ranging between 10.0 and 100.0 L/day. A significant association between water intake and milk yield was found (P = <0.0001). R^2 = 9.40 % and the coefficient was 0.096, meaning milk yield is expected to increase approximately 0.1 L for every 1 L increase in water intake. 95.6 % of households stated using underground water, while the remaining 4.4 % stated using water supplied by the government.

Hoof Status Scoring and Lameness Incidence

Hoof status scoring was performed on a total of 306 animals (see Table 3). About 95.5 % of animals were scored as category 1, while remaining 4.5 % were scored as category 2. No animals were scored into category 3 or 4.

An incidence rate of lameness was calculated. With 25 cases of lameness in approximately 800 animals in a year, the incidence rate in this population was found to be approximately 3 cases of lameness/100 cow-years.

Only 3 % of households stated that they practiced hoof trimming, while 37 % stated that they performed footbaths.

Table 4 - Distribution of hoof status scores in surveyed dairy cattle in Bihar, India.

Hoof score	**Number of animals (Total n=306)**	**Percentage**
1	292	95.5 %
2	14	4.5 %
3	0	0.0 %
4	0	0.0 %

Discussion

The average household herd had 3.5 animals (cattle and buffalo), which is a greater number when compared to earlier studies. In a study by Singh et al. (2013) a majority of dairy farmers in Bihar are stated to have 1-2 animals. An absolute majority of cattle (97.8 %) included in the study were crossbred. This is radically different compared to a study by Staal et al. (2008), where levels of crossbreeds in Bihar are stated to be 10-25 %, as compared to national levels of 13.3 % crossbred animals. Unfortunately, no data was collected on what breeds were included in crossbred animals, but according to personal communication with local sources the most common combination was 2-way crosses between animals of an indigenous breed with Holstein or Jersey. This was also consistent with the appearance of many of the animals surveyed.

Mean daily milk yield per lactating animal on farms in this study was estimated to be 8.3 L/day. This is a much higher number when compared to milk yields stated in a previous study in Bihar where mean daily milk yield per animal was 2.7 kg/day (Singh et al., 2010). Studies from other parts of India has stated mean daily milk yields of between 3.0-4.2 L/day for indigenous breeds and between 5.8-9.6 L/day for crossbred animals (Bardhan & Sharma, 2013; Duncan et al., 2013), or a mean daily milk yield of 5.2 kg/day for indigenous and crossbred animals combined (Patil & Udo, 1997). Seeing as vast majority of animals in this study were crossbred (97.8 %), comparisons between the mean daily milk yield of this study and that of crossbred animals described above should be considered reasonable. Compared to the mean daily milk yields of between 5.8-9.6 L/day for crossbred animals described by Bardhan & Sharma (2013) and Duncan et al. (2013), a mean daily milk yield of 8.3 L/day could then be considered rather reasonable.

Collection of data on milk yield in this study was collected on farm level as the mean total milk yield per day from each farm during the last 1 year, although, since it is recall data, the data is likely to be representative mainly of recent time. Mean total milk yield of the farm was then divided by the number of lactating animals to create a mean milk yield per day and animal on the farm. This means that the mean milk yield per animal is not a true value of individual production, but merely a way of relating the milk yield on each farm to the number of contributing lactating animals. Only animals in milk at the time of data collection were used in this calculation as calving intervals and dry periods were expected to be long. This might however not be true in every household, leading to an error in the mean milk yield. Furthermore, as only total daily milk yield per farm was included as a factor, the production could not be related to the lactation stage of the contributing animals. Put together this could mean that the mean milk yield of 8.3 L/day for each animal on each of the farms included could be considered uncertain, as production on the individual level can vary greatly due to factors such as health status, stage of lactation and current amount and quality of feed given.

In 98 % of households it was reported that animals were fed two times per day. It was however observed during the study that animals rarely had access to any feed during the visits. Cattle being ruminants, it is important for them to be able to have access to feed during large portions of the day (Albright, 1992). At the same time, 99.2 % of animals were judged to have RFS of 2, 3 or 4, all of which can be considered normal depending of which stage of lactation the animal is in (Zaaijer & Noordhuizen, 2003). In addition, almost all included animals were assessed to have an acceptable BCS, which indicates that total energy intake was in fact adequate in an absolute majority of cases.

In total, 83 % of households reported using concentrate in the feed, and inclusion of concentrate was found to be positively correlated with milk yield. Inclusion of other investigated feed items (dry fodder, green fodder) in the feed was not found to be correlated with milk yield. This is in accordance with other studies that showed positive effects on milk yield from the inclusion of concentrate in the feed (Muraguri et al., 2004; Reid et al., 2015). In an Indian study by Patil & Udo (1997) milk yield in Holstein-Friesian crossbreeds increased with 1.28 kg per 1 kg of concentrate included in the feed. Inclusion of concentrate in the feed of animals should therefore be expected to lead to an increase of daily milk yield.

Out of all included animals, 64.4 % were assessed to have a body condition of 3, while 99.0 % of animals were scored to have a body condition of between 2 and 4. A scoring of between 2 and 4 can be considered normal, depending on which state of lactation the individual being assessed is in. Based on this, the body condition of animals included can be said with relative certainty to be satisfactory. Since milk production was only collected at farm level, the association with BCS was not assessed. Other studies have shown that BCS and milk yield could be correlated (Domecq et al., 1997; Grainger et al., 1982; Waltner et al., 1993), and it is possible that they would have been associated in this study as well if it had been possible to collect data on milk yield from each individual animal. As BCS has been shown to vary according to the stage of lactation of the individual animal (Wildman et al., 1982), it would also have been necessary to include data on lactation stage.

Mean reported water intake per lactating animal and day was 35.29 L/day, with values ranging between 10.0 and 100.0 L/day. As no studies on water intake from India has been found, comparisons will have to be made with studies from other countries. Most studies are however performed in countries with temperate climate and high yielding animals, which makes comparisons difficult since water intake is heavily influenced by climate and milk yield. Mean values of daily water intake in studies range between 43 L/day (Andersson, 1987) and 135 L/day (Kadzere et al., 2002), with mean daily milk yields in the studies about 22.5 L ECM/day and 41.5 kg/day respectively. Further it's difficult to compare production values in old studies with results in current research, as milk yields have increased dramatically the last few decades. These factors make it hard to assess whether a mean water intake of 35.29 L/day is adequate for a mean milk yield of 8.3 L/day in the climate of the surveyed area. The fact that a significant association was established between water intake and milk yield indicates, however, that there is a potential for increased milk yield through an increase of water intake. This could be interpreted as a sign that the mean water intake is in fact limiting the milk production. An observation from the field when conducting this study was that animals seldom had ad libitum access to water, which could further the notion that water intake was in fact inadequate.

An absolute majority of households, 95.6 %, stated using underground water. This makes water quality uncertain since underground water from wells can be expected to vary according to local environment and soil quality. Further research would therefore be needed to assess whether water quality of underground water in the area could be deemed satisfactory.

A majority of cattle (95.5 %) included in this study for hoof scoring were estimated to have hooves of normal length and angle, and the annual incidence rate for lameness was 3 cases/100 cattle. This is an extremely low annual incidence rate for lameness compared to results from studies from other parts of India (38 cases/100 cattle, Singh et al., 2011) as well as compared to studies from other countries (55 cases/100 cattle in UK, Clarkson et al., 1996). The results from this study therefore seem to suggest that lameness and hoof lesions are in fact not of major importance in Bihar. It is however probably hard to evaluate the prevalence of hoof lesions based on the visual evaluation that was performed in this study. This would require further investigations including examination of the underside of the hoof as well as an evaluation of the animals in motion. These kinds of evaluations were however not deemed feasible to perform during the field conditions present during this study, which is why an unevaluated scoring chart was used. Furthermore, there may be a chance that lameness was not reported correctly due to miscommunication and recall bias. All in all however, the results of this study suggest that lameness and hoof lesions should not be considered major animal health and welfare issues in Bihar.

One large source of error when comparing results in this study to results in literature is the fact that a majority of studies are conducted on high yielding, highly specialized dairy breeds kept in temperate climate. Climate in Bihar is varying but mostly subtropical, meaning humidity and average temperature are both most likely significantly higher compared to those reported in most studies. Also the fact that cows in Bihar are not of high yielding dairy breeds further complicates comparisons, even though the percentage of crossbreeds (97.8 %) in this study are much higher than anticipated.

Several problems presented themselves during the collection of data on site in Bihar. The questionnaire was written in English to allow for the results to be read and entered by all members of the group. The level of understanding of English amongst the group of interpreters was however of varying quality, which lead to problems with some questions being given non-applicable answers. These problems were addressed as they were discovered during the course of the study, but still affect the reliability of the number and quality of the answers to some of the questions included.

According to the original plan, households and the animals included from each household were to be randomly selected. This was due to practical issues in selection, partly due to some farmers being unwilling to consent to allowing more than one animal to be included in the study although additional eligible animals were present on the farm. Also sometimes adjacent households were included out of convenience. The fact that the selection process was not completely randomized means that the farms may not be considered representative of the entire study population, and hence results should be interpreted with caution. For future research in Bihar, a completely randomized study is recommended to correctly evaluate the animal health in the state.

Assessments of hoof status and BCS were both subjective which decreases the reliability and the reproducibility of the results. BCS-scoring was performed according to a scoring systems that all of evaluators (including the author) were used to working with, which should be expected to improve the reliability of the results. Hoof status scoring was based on a scoring system used in an unpublished master degree thesis. This scoring system was chosen due to lack of other suitable scoring systems, although the use of this non-evaluated system decreases reliability. For the first few days the initial assessments of animals were performed by all three evaluators individually, followed by discussions of these individual assessments. This should be expected to lead to some harmonization of assessments which should improve the reliability of the results.

CONCLUSION

This study provides an updated view on dairy farming in Bihar. Smallholders still dominate the dairy farming in Bihar, with a mean number of 3.5 animals per household. Crossbred animals constituted the vast majority (97.8 %) of animals included in this study. These numbers are however not in line with numbers from earlier studies, where crossbred animals are stated to constitute 10-25 % and 13.3 % of the total cattle population in Bihar and India respectively (Staal et al., 2008). Mean daily milk yield in households was 8.3 L/day for each lactating animal, which is a major increase compared to numbers in previous studies. Body condition and rumen fill were both found to be within adequate ranges, indicating a satisfactory energy intake. Intake of drinking water and inclusion of concentrate in feed rations were both found to be significantly associated with increased milk yield ($P < 0.05$). A majority of animals (95.5 %) were deemed to have hooves of normal length and angle and the annual incidence rate of lameness 3 cases/100 cows, which is extremely low compared to other studies. This might be seen as an indication that hoof lesions are not a major problem in Bihar. However, since only visual assessments and questionnaires were used to assess status of hooves, and the fact that selection of animals was not completely randomized, further research would be needed to assess this. In conclusion, this study suggests a focus on water and feeding of concentrates in future initiatives to increase milk yield in Bihar.

REFERENCES

Alban, L., Agger, J. F. & Lawson, L. G. (1996). Lameness in tied Danish dairy cattle: the possible influence of housing systems, management, milk yield, and prior incidents of lameness. *Preventive Veterinary Medicine,* 29 (1996):135-149.

Albright, J. L. (1992). Feeding Behavior of Dairy Cattle. *Journal of Dairy Science*, 76:485-498.

Alhassan. W. S. & Owusu, D. Y. (1980). Lactation responses of dairy cattle to concentrate feeding in the humid tropics. *Tropical Animal Health and Production (1980)*, 12:171-176

Allen, M. S. (2000). Effects of Diet on Short-Term Regulation of Feed Intake by Lactating Dairy Cattle. *Journal of Dairy Science*, 83:1598-1624.

Andersson, M. (1987). Effects of Number and Location of Water Bowls and Social Rank on Drinking Behaviour and Performance of Loose-Housed Dairy Cows. *Livestock Production Science*, 17 (1987):19-31.

Andersson, M., Schaar, J. & Wiktorsson, H. (1984). Effects of Drinking Water Flow Rates and Social Rank on Performance and Drinking Behaviour of Tied-up Dairy Cows. *Livestock Production Science*, 11 (1984):599-610.

Auldist, M. J., Marett, L. C., Greenwood, J. S., Wright, M. M., Hannah, M., Jacobs, J. L. & Wales, W. J. (2016). Milk production responses to different strategies for feeding supplements to grazing dairy cows. *Journal of Dairy Science*, 99:657-671.

Bardhan, D. & Sharma, M. L. (2013). Techinal efficiency in milk production in underdeveloped production environment of India. *SpringerPlus 2013,* 2:65:1-7. doi:10.1186/2193-1801-2-65.

Barielle, N., Beaudeau, F., Billon, S., Robert, A. & Faverdin, P. (2003). Effects of health disorders on feed intake and milk production in dairy cows. *Livestock Production Science*, 83 (2003):53–62.

Barkema H. W., Westrik, J. D., van Keulen, K. A. S., Schukken, Y. H. & Brand, A. (1994). The effects of lameness on reproductive performance, milk production and culling in Dutch dairy farms. *Preventive Veterinary Medicine*, 20 (1994):249-259.

Boudon, A., Peyraud, J.-L., Faverdin, P., Delagarde, R., Delaby, L. & Chaves, A. V. (2009). Effect of rumen fill on intake of fresh perennial ryegrass in young and mature dairy cows grazing or zero-grazing fresh perennial ryegrass. *Animal (2009)*, 3:12: 1706-1720. doi:10.1017/S1751731109990486.

Burfeind, O., Sepúlveda, P., von Keyserlingk, M. A. G., Weary, D. M., Veira, D. M. & Heuweiser, W. (2010). Technical note: Evaluation of a scoring system for rumen fill in dairy cows. *Journal of Dairy Science*, 93:3635-3640.

Cardot, V., Le Roux, Y. & Jurjanz, S. (2008). Drinking Behavior of Lactating Dairy Cows and Prediction of Their Water Intake. *Journal of Dairy Science*, 91:2257–2264.

Clarkson, M. J., Downham, D. Y., Faull, W. B., Hughes, J. W., Manson, F. J., Merritt, J. B., Murray, R. D., Russell, W. B., Sutherst, J. E. & Ward, W. R. (1996). Incidence and prevalence of lameness in dairy cattle. *Veterinary Record (1996),* 138: 563-567. doi:10.3168/jds.2009-3044.

Domecq J. J., Skidmore, A. L., Lloyd, J. W. & Kaneene, J. B. (1997). Relationship Between Body Condition Scores and Milk Yield in a Large Dairy Herd of High Yielding Holstein Cows. *Journal of Dairy Science*, 80:101–112.

Dooho, I. R. & Martin, S. W. (1983). Disease, Production and Culling in Holstein-Friesian Cows: IV. Effects of Disease on Production. *Preventive Veterinary Medicine*, 2 (1984):755-770.

Duncan, A. J., Teufel, N., Mekonnen, K., Singh, V. K., Bitew, A. & Gebremedhin, B. (2013). Diary Intensification in developing countries: effects of market quality on farm-level feeding and breeding practices. *Animal (2013)*, 7:12:2054-2062.

Edmonson, A. J., Lean, I. J., Weaver, L. D., Farver, T. & Webster G. (1989). A Body Condition Scoring Chart for Holstein Cows. *Journal of Dairy Science*, 72:68–78.

Enting, H., Kooij, D., Dijkhuizen, A. A., Huime, R. B. M. & Noordhuizen-Stassen, E. N. (1997). Economic losses due to clinical lameness in dairy cattle. *Livestock Production Science*, 49 (1997):259-267.

FAO (2012). *FAO/INFOODS Density Database Version 2.0*. Rome: FAO.

Fourichon, C., Seegers, H., Barielle, N. & Beaudeau, F. (1998). Effects of disease on milk production in the dairy cow: a review. *Preventive Veterinary Medicine*, 41 (1999):1-35.

Gabbi, A. M., McManus, C. M., Zancia, M. B., Stumpf, M. T., Barbosa, R. S., Fruscalso, V., Neto, A. T., Schmidt, F. A. & Fischer, V. (2016). Milk traits of lactating cows submitted to feed restriction. *Tropical Animal Health and Production (2016)*, 48:37-43.

Gearhart, M. A., Curtis, C. R., Erb, H. N., Smith, R. D., Sniffen, C. J., Chase, L. E. & Cooper, M. D. (1990). Relationship of Changes in Condition Score to Cow Health in Holsteins. *Journal of Dairy Science*, 73:3132-3140.

Government of Bihar (2014). *Economic Survey* 2013-2014. Patna: Government of Bihar, Finance Department. http://finance.bih.nic.in/Documents/Reports/Economic-Survey-2014-EN.pdf. [2015-12-09].

Grainger, C., Wilhelms, G. D. & McGowan, A. A. (1982). Effect of body condition at calving and level of fedding in early lactation on milk production of dairy cows. *Australian Journal of Experimental Agriculture and Animal Husbandry*, 22:9-17.

Green, L. E., Hedges, V. J., Schukken, Y. H., Blowey, R. W. & Packington, A. J. (2002). The Impact of Clinical Lameness on the Milk Yield of Dairy Cows. *Journal of Dairy Science*, 85:2250–2256.

Hultgren, J., Mankse, T. & Bergsten, C. (2004). Associations of sole ulcer at claw trimming with reproductive performance, udder health, milk yield, and culling in Swedish dairy cattle. *Preventive Veterinary Medicine*, 62 (2004):233–251.

Istasse, L., Reid, G. W., Tait, C. A. G. & Ørskov, E. R. (1986). Concentrates for dairy cows: Effects of feeding method, proportion in diet and type. *Animal Feed Science and Technology*, 15 (1986):167-182.

Jílek, F., Pytloun, P., Kubešová, M., Štípková, M., Bouška, J., Volek, J., Frelich, J. & Rajmon, R. (2008). Relationships among body condition score, milk yield and reproduction in Czech Fleckvieh cows. *Czech Journal of Animal Science*, 53:357-367.

Kadzere, C. T., Murphy, M. R., Silanikove, N. & Maltz, E. (2002). Heat stress in lactating dairy cows: a review. *Livestock Production Science*, 77:59–91.

Kawashima, C., Karaki, C., Munakata, M., Matsui, M., Shimizu, T., Miyamoto, A. & Kida, K. (2016). Association of rumen fill score and energy status during the close-up dry period with conception at first artificial insemination in dairy cows. *Animal Science (2016)*. doi: 10.1111/asj.12555.

Keady, T. W. J., Mayne, C. S., Fitzpatrick, D.A & McCoy, M. A. (2001). Effect of Concentrate Feed Level in Late Gestation on Subsequent Milk Yield, Milk Composition, and Fertility of Dairy Cows. *Journal of Dairy Science*, 84:1468-1479.

King, K. R. & Stockdale, C. R. (1981). Milk yield of dairy cows given restricted access to water in a Mediterranean-type climate. *Australian Journal of Experimental Agriculture and Animal Husbandry*, 21:167-171.

Kume, S., Nonaka, K., Oshita, T. & Kozakai, T. (2010). Evaluation of drinking water intake, feed water intake and total water intake in dry and lactating cows fed silages. *Livestock Science*, 128 (2010):46–51.

Lukas, J. M., Reneau, J. K. & Linn, J. G. (2008). Water Intake and Dry Matter Intake Changes as a Feeding Management Tool and Indicator of Health and Estrus Status in Dairy Cows. *Journal of Dairy Science*, 91:3386-3394.

Meyer, U, Everinghoff, M., Gädeken, D. & Flachowsky, G. (2004). Investigations on the water intake of lactating dairy cows. *Livestock Production Science*, 90 (2004):117–121.

Muraguri, G. R., McLeod, A. & Taylor, N. (2004). Estimation of Milk Production from Smallholder Dairy Cattle in the Coastal Lowlands of Kenya. *Tropical Animal Health and Production*, 36(7):673-684.

NRC (2001). *Nutrient Requirements of Dairy Cattle*. 7th Revised Edition. Washington, D. C.: National Academy Press.

Onyiro, O. M., Offer, J. & Brotherstone, S. (2008). Risk factors and milk yield losses associated with lameness in Holstein-Friesian dairy cattle. *Animal (2008)*, 2:8 :1230–1237.

Patil, B. R. & Udo, H. M. J. (1997). The Impact of Crossbred Cows in Mixed Farming Systems in Gujarat, India: Milk Production and Feeding Practices. *Asian-Australasian Journal of Animal Sciences*, 10(3):253-259.

Rajala-Schultz, P. J., Gröhn, Y. T. & McCulloch, C. E. (1999). Effects of Milk Fever, Ketosis, and Lameness on Milk Yield in Dairy Cows. *Journal of Dairy Science*, 82:288-294.

Reid, M., O'Donovan, M., Murphy, J. P., Fleming, C., Kennedy, E. & Lewis, E. (2015). The effect of high and low levels of supplementation on milk production, nitrogen utilization efficiency, and milk protein fraction in late-lactation dairy cows. *Journal of Dairy Science*, 98:5529-5544.

Roche, J. R., Dillon, P. G., Stockdale, C. R., Baumgard, L. H., VanBaale, M. J. (2004) Relationships Among International Body Condition Scoring Systems. *Journal of Dairy Science*, 87:3076-3079.

Roche, J. R., Friggens, N. C., Kay, J. K., Fisher, M. W., Stafford, K. J. & Berry, D. P. (2009). Invited review: Body condition score and its association with dairy cow productivity, health, and welfare. *Journal of Dairy Science*, 92:5769-5801.

Roche, J. R., Lee, J. M., Macdonald, K. A. & Berry, D. P. (2007). Relationships Among Body Condition Score, Body Weight, and Milk Production Variables in Pasture-Based Dairy Cows. *Journal of Dairy Science*, 90:3802-3815.

Rowlands, G. J. & Lucey, S. (1986). Changes in Milk Yield in Dairy Cows Associated With Metabolic and Reproductive Disease and Lameness. *Preventive Veterinary Medicine*, 4 (1986):205-221.

Ruegg, P. L & Milton, R. L. (1995). Body Condition Scores of Holstein Cows on Prince Edward Island, Canada: Relationships with Yield, Reproductive Performance, and Disease. *Journal of Dairy Science*, 78:552-564.

Singh, R. K. P. (2013). Livestock Research and Development Priorities for Bihar and Odisha Social Science Research Network, http://dx.doi.org/10.2139/ssrn.2391607. [2015-12-09]

Singh, Y., Lathwal, S. S., Chakravarty, A. K., Gupta, A. K., Mohanty, T. K., Raja, T. V., Dangi, R. L. & Roy, B. K. (2011). Effect of lameness (hoof disorders) on productivity of Karan Fries crossbred cows. *Animal Science Journal (2011)*, 82: 169-174.

Singh, K. M., Singh, R. K. P., Jha, A. K. & Meena, M. S. (2010). Dynamics of Livestock Sector in Bihar: A Temporal Analysis. *Agricultural Situation in India*, LXVI (No.13): 687-702.

Sogstad, Å. M., Østerås, O., Fjeldaas, T. & Refsdal, A. O. (2007). Bovine Claw and Limb Disorders at Claw Trimming Related to Milk Yield. *Journal of Dairy Science*, 90:749–759.

Spiekers, H., Klünter, A.-M., Potthast, V. & Pfeffer, E. (1991). Effects of different concentrate levels on milk yield, feed intake, live weight change, health and reproduction in dairy cows. *Livestock Production Science*, 28:89-105.

Staal, S. J., Pratt, A. N. & Jabbar, M. (2008). *Dairy Development for the Resource Poor Part 3: Pakistan and India Dairy Development Case Studies*. Rome: FAO (PPLPI Working Paper No. 44-3).

Steiger Burgos, M., Senn, M., Sutter, F., Kreuzer, M. & Langhans, W. (2001). Effect of water restriction on feeding and metabolism in dairy cows. *American Journal of Physiology Regulatory Integrative Comparative Physiology*, 280:R418-R427

Walnter, S. S., McNamara, J. P & Hillers, J. K. (1993). Relationship of Body Condition Score to Production Variables in High Producing Holstein Dairy Cattle. *Journal of Dairy Science*, 76:3410-3419.

Warnick, L. D., Janssen, D., Guard, C. L. & Gröhn, Y. T. (2001). The Effect of Lameness on Milk Production in Dairy Cows. *Journal of Dairy Science*, 84:1988-1997.

Wildman, E. E., Jones, G. M.,Wagner, P. E., Boman, R. L., Troutt, JR., H. F. & Lesch, T. N. (1982). A Dairy Cow Body Condition Scoring System and Its Relationship to Selected Production Characteristics. *Journal of Dairy Science*, 65:495-501.

Willms, W. D., Kenzie, O. R., McAllister, T. A., Colwell, D., Veirs, D., Wilmshurst, F., Entz, T. & Olson, M. E. (2002). Effects of Water Quality on Cattle Performance. *Journal of Range Management*, 55:452-460.

Zaaijer, D. & Noordhuizen, J. P. T. M. (2003) A novel scoring system for monitoring the relationship between nutritional efficiency and fertility in dairy cows. *Irish Veterinary Journal*, 56(3):1-12. https://www.researchgate.net/publication/46628199. [2016-02-18].

Zahid, U. N., Randhawa, S. S., Hussain, S. A., Randhawa, S.S., Mahajan, V. & Dua, K. (2014). Claw Lesions Causing Clinical Lameness in Lactating Holstein Frisian Crossbred Cows. *Veterinary Medicine International Volume 2014*:1-8. doi:10.1155/2014/764689.