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REVIEW PAPER

Feeding and handling of dairy cattle: An integrative review

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Abstract: Global cattle dairy sector has shown significant development during the past few years due to many improvements in some areas. Two of the major areas that have improved are; cattle nutrition, feed types and feeding systems & feeding frequency. Regarding the cattle nutrition, there were quite a few studies carried out to identify the contribution by each nutrient on milk yield and its properties. Some studies were conducted to investigate the impact on the milk yield and its properties by different sources of nutrients. Another area that has recently advanced is the feed types provided to the animals. Several studies have investigated the benefits as well as disadvantages of different feed types. Same as cattle nutrition, there were several research projects conducted to determine the impact of feeding systems and feeding frequencies on milk yield and its properties. For example, studies regarding impact of total mixed rations on milk properties were carried out worldwide. Findings of those studies have greatly contributed to the modern development of the dairy sector. On the other hand, to improve the nutrition of the cattle and to have improved feeding systems; financial requirements are one of the main limiting factors. Therefore, some studies are concluded to determine the cost effectiveness of new methods and practices. This review focuses on the global dairy sector; dairy cattle nutrition, feeding systems & feeding frequency, cost for dairy cattle concentrates and feed. Those sections are described comprehensively.

Keywords: Cattle nutrition, Cattle feeding systems, Cattle feed types, Dairy cattle, Dairy farming cost

Abbreviation: NEL = Net Energy for Lactation; ME = Energy requirement for the pregnancy period; D = Gestation days; CBW = Calf Birth Weight; NEM = Net Energy for Maintenance; NEL = Net Energy for Lactation; TDN = Total Digestible Nutrients; RDN = Rumen Degradable Nitrogen; UDN = Undegradable Dietary Nitrogen; BW = Body Weight; DMI = Dry Matter Intake; TMR = Total Mixed Rations; MUN = Milk Urea Nitrogen; NFC = Non-Fibre Carbohydrates; CP = Crude Protein; DIP = Degradable Intake Protein; SP = Soluble Protein; UIP = Undegradable Intake Proteins; NDF = Neutral Detergent Fibre; ADF = Acid Detergent Fibre

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Introduction

Over the past 25 years, world cows' milk production has increased significantly. Milk yield per cow has increased about 2% per year. In 1980 milk yield of an average cow is about 5,500 kg per year/15.06 kg per day and in 2005 milk yield of an average cow is about 8,500kg per year/23.29kg per day (Eastridge et al., 2006). FAO (2018) report has revealed that the dairy cow population was nearly 274 million in 2016. Dairy cow populations according to the countries in 2014, 2015 & 2016 were shown in Table 1. According to FAO (2018) any type of nutrient can affect the dairy production of a cow. Cows require a continuous supply of nutrients for their maintenance, growth, milk production and especially during pregnancy. However, main nutrients that must be considered in a cow's diet are energy and protein. Hence, most of the time energy and protein are the limiting factor for dairy production. Harris (1992) proclaimed that the nutritional requirements for maintenance and milk production vary according to the size of the animal. Kavanagh (2016) has given guidelines to investigate nutrition related milk quality issues. Main milk quality issues that can be encountered are; low milk protein, low milk fat, low milk lactose. Main reasons that lead to low milk protein are:

- Genetically cows are not capable to produce milk with high protein contents
- Lower energy supply due to inadequate dry matter intake due to (i) Limited supply of grass, low grass digestibility, overestimation of grass supply and poor grazing conditions. (ii) Lower energy grass and low digestible grass supply due to grazing high pre-grazing covers. (iii) Poor quality forages.
- Stage of lactation; because generally milk protein percentage can be reduced after 4 – 6 weeks.
- Late calving date shows lower milk protein values in the mid-season.
- High concentrated oil diets.
- Ingredient type; high-quality grass supply to pasture fed cows and 20% - 25% of total starch supply to a compound fed cow may increase the milk protein content.

Low milk fat can be due to:

- Supplying low fibre grass with high levels of concentrate feeds.
- Grazing on low cover lush grass with low fibre.
- Supplying high levels of cereals.
- Supplying high levels of rapidly degradable carbohydrates.

Reasons for low lactose contents in milk are:

- Stage of the lactation; milk yield and lactose content degrade in the late lactation period.
- Poor quality grass or poor grass conditions
- High somatic cell counts.

Contrasting with many investigators in the field, Knowlton et al. (2003) has indicated that the four main nutrients required for dairy cattle for their maintenance and milk production are water, energy, vitamins and minerals. Dairy cattle farming industry is growing as per the requirements of the growing global population. Although the growth of the industry in the developing nations is not at the expected rate due to both technical and economical limitations. In this review; prime aspects of cattle feeding, nutrition and important practices of cattle handling are discussed, aiming to provide basic guidance to dairy farmers.

Table 1 Countries by cow numbers

Ranks	Countries	2014	2015	2016
1	India	45,949,160	47,164,610	48,610,350
2	Brazil	23,027,951	21,110,916	19,678,817
3	China	12,560,603	11,859,204	12,717,960
4	Ethiopia	11,381,972	11,326,490	11,833,179
5	Pakistan	11,725,000	12,167,000	11,676,312
6	United States of America	9,257,000	9,314,000	9,328,000
7	Sudan	7,686,000	8,708,000	7,876,089
8	South Sudan	7,372,000	7,375,129	7,380,947
9	Russian Federation	7,572,692	7,362,338	7,194,354
10	Kenya	5,750,000	6,450,201	7,013,642
11	UK	1,851,000	1,901,000	1,822,000
	World	273,444,339	272,606,411	273,782,776

*Average global cows per farm value are 3.1 (International Fact Checking Network 2017).

Dairy cattle nutrition

Water

The main component of a cow's body and milk is water. A cow's 71 - 73% of the non-fat body weight is water and also milk contains 87% water. Therefore water is the main nutritional requirement of a cow. Generally, two or three times greater contents of water than food is being consumed by a cow. Thus access to water at all the time is highly recommended (Knowlton et al., 2003). Murphy (1992) declares that to maximise the milk yield, supplying a sufficient amount of suitable type water source is essential. Furthermore, the author reveals, through reducing the sodium content of the diet, consumption of water can be reduced without affecting the milk production. In high tempered environments, supplying chilled water may increase the milk yield and the dry matter intake. However, quality of the water source is the most important factor that affects the intake potential and animal health (Eastridge, 2006).

Energy

When considering energy; metabolisable energy, urine, gases and body heat are the required forms of outputs for the maintenance and the production (FAO). National Research Council - USA (2001) states that the Net Energy for Lactation (NEL) of a lactating cow for maintenance is 0.080Mcal/ kg bodyweight. NEL for milk is equal to the sum of the heats of combustion of individual milk components. And combustion energies of milk fat, milk protein and milk lactose are 9.29 M cal/kg, 5.71 Mcal/kg and 3.95 Mcal/kg, respectively. While walking 0.00045 Mcal/kg of heat is produced per kilometre. Therefore according to the feeding system (compound pasture fed), the walking activity of a cow varies and the energy requirement for the activity varies accordingly. The energy requirement for the pregnancy period (ME) depends on the gestation days (D) and Calf Birth Weight (CBW). It is expressed through an equation which is:

$$\text{ME (Mcal/day)} = [0.00318 \times D - 0.0352) \times (CBW/ 45)]/ 0.14$$

According to Harris (1992) energy requirements are categorised into categories which are; Net Energy for Maintenance (NEM), Net Energy for Lactation (NEL) and Total Digestible Nutrients (TDN). NEL and NEM are expressed in mega calories (Mcal) and TDN is expressed as pounds. NEL is the energy requirement for milk production. Since fat is high in energy content, cows producing milk in higher fat concentrates need to be supplied with more energy per pound of milk. Knowlton et al. (2003) have stated that the second most important factor in cattle nutrition is energy. Energy is needed to produce milk, for growth, for pregnancy and maintenance. Main energy sources are protein, carbohydrate and fat. The maintenance energy is described as the required energy for the cattle for general metabolism before growth of the foetus, milk production or pregnancy. Gross energy is defined as the ingested energy. Digestible energy is interpreted as gross energy without the energy lost in faeces. Metabolisable energy is digestible energy without the energy loss in urine and gases. Metabolise energy is the utilizable form of energy required for the maintenance. Cows are getting carbohydrates as starch, cellulose and hemicellulose. In the rumen microbes digest these complex carbohydrates into simple sugars or monosaccharides which are later converted into volatile fatty acids again by microbes. They are absorbed across the rumen wall and small intestine. Fat is mainly ingested through supplements such as oilseeds and also considered as a high energy component for cattle nutrition.

Carbohydrate

Allen et al. (2014) have given the nutrient (specially the carbohydrate) requirements according to the lactation stage of the cow. Nutrient supply of far-off dry cows and close-up dry cows must meet the energy requirement, but the requirement should not be exceeded. Grain sources are recommended as the supplements for far-off dry cows. Meanwhile maintaining the rumen fill throughout the transition period is also recommended. A limited amount of moderately fermentable starch is recommended to stimulate insulin and to limit the fat metabolism. Also, non-forage fibre sources are not recommended as they are not supplying glucose or not aid in rumen fill. For fresh cows, the goal is to maintain the rumen fill and to supply required glucose amounts to fulfil the energy requirement for the lactation. Therefore to supply glucose precursors, a higher amount of starch must be fed to the cow. To supply more glucose and to avoid depressed feed intakes or reduced rumen pH, supplements with moderate rumen fermentability and high digestibility are recommended such as dry ground corn. Rumen fermentability is around 60% and digestibility is more than 90%. On the other hand high-producing cows also have a higher glucose requirement to supply energy for milk production and body maintenance. The recommendation is to supply diets with low rumen fill such as forage with low neutral detergent fibre and highly fermentable starch because of high-producing cow response well to such diets. Therefore starch sources such as low density steamed flaked corn, high-moisture corn, rolled barley etc. can be given as supplements. However, the starch rations should be in between the 25% to 30% range. Supplements such as ground wheat provide more starch than the required amount. Even though these types of supplements increase the peak milk yield of a cow, it will be sooner reduced and the body condition score of the animal begins to decrease rapidly in the early lactation. The goal of the maintenance group cows' diet is to supply nutrients that are enough to maintain the body condition score of the animal, while maintaining or increasing the milk yield. Supplying high starch concentrates will increase the body condition score rather than maintain which will increase the plasma glucose levels and the insulin levels and increases the risk of metabolic disease. The optimal diet for high-producing cows at the later lactation is, fed with high fermentable starch. It will decrease the feed intake and milk yield which lowers the risk of metabolic diseases. Addition of non-forage fibre sources such as beet pulp, corn gluten feed, soy hulls etc. to the diets is encouraged to dilute the high starch amounts (Allen et al., 2014).

Protein

FAO (2010) states all the protein available in a cattle diet will not pass through the rumen at the same time. Due to the microbial activity in the rumen, part of the protein get degraded and the remaining proteins are being absorbed in the small intestine as amino acids. According to the degradability in the rumen, crude protein can be divided into two categories; Rumen Degradable Nitrogen (RDN) and Undegradable Dietary Nitrogen (UDN). In the rumen, non-protein nitrogen such as urea and inorganic nitrogen sources from plants are completely degraded by the microbes and they synthesize proteins. These proteins are digested in the animal's small intestine later and absorbed as amino acids for the metabolism. Optimal conditions for microbial degradation occur if the animal is being provided with sufficient energy. If the energy is lacking, the activity rate of the rumen drops below the normal rate and this leads to reduced intake of feeds. As a result, dairy production decreases. On the other hand, UDN containing protein passes through the rumen and is directly digested in the small intestine due to the resistance against the microbial degradation. Fish meal is one of the examples for the UDN sources. Low productive cows are able to fulfil the protein requirement entirely through the microbial protein. However, UDN is essential for the high yielding cows to fulfil their protein requirement (FAO, 2010).

According to the FAO (2010) standards, energy and protein requirements are included in Table 2 and Table 3. According to Harris (1992), energy requirements can be categorised into Net Energy for Maintenance (NEM), Net Energy for Lactation (NEL) and Total Digestible Nutrients (TDN). NEL and NEM are expressed in megacalories (Mcal) and TDN is expressed in pounds. NEL is the energy requirement for milk production. Since the energy content in fat is high, cows producing milk with high fat contents need to be supplied with more energy per pound of milk. Also, the author declares that high producing cows require comparatively more essential amino acids and they must be fulfilled through either microbial protein or UDN. The suggested amount of UDN of a cattle diet must be 35% to 40%. During processing and with the heat treatment the amount of RDN rises in different feeds. Examples of RDN sources are distillers' grains, brewers' grains, corn gluten meal, blood meal, meat and bone meal, feather meal and heat treated soybeans. Nutrient requirements are shown in Table 4 and Table 5 as per details described by the author (Harris, 1992).

Table 2 Nutrients requirement of metabolisable energy (ME), in Mega Joule (MJ), and crude protein (CP) for maintenance of each cow according to body weight

Body weight/(kg)	Energy requirement/MJ ME/day	Protein requirement/kg CP/day
300	34.6	0.288
350	38.8	0.324
400	42.9	0.358
450	46.9	0.391
500	50.8	0.423
550	54.5	0.454

Table 3 Metabolisable Energy (ME) and crude protein (CP) for production per Kilogram of milk depending on fat contents

Fat percentage	Metabolisable energy (MJ ME/ kg of milk)	Crude protein (kg/kg of milk)
3.4	4.9	0.081
3.6	5.0	0.082
4.0	5.3	0.085

Table 4 Daily nutrient requirements for maintenance of mature lactating cows

Body weight (lb)	Crude protein (lb)	NEL (Mcal)	TDN (LB)	Ca (lb)	Phosphorus (lb)	Vitamin A (1000 IU)	Vitamin D (1000 IU)
1000	0.98	7.86	7.58	0.041	0.029	34	14
1200	1.18	9.02	8.70	0.049	0.034	41	16
1400	1.37	10.12	9.76	0.057	0.040	48	19

Table 5 Nutrient contents required with respect to the milk fat content

Fat (%)	Crude protein (lb)	NEL (Mcal)	TDN (lb)	Ca (lb)	Phosphorus (lb)
3.0	0.073	0.29	0.280	0.0027	0.0017
3.5	0.079	0.31	0.301	0.0030	0.00018
4.0	0.86	0.33	0.322	0.0032	0.0020
4.5	0.092	0.36	0.343	0.0035	0.0021
5.0	0.100	0.38	0.364	0.0037	0.0023
5.5	0.105	0.40	0.385	0.0039	0.0024

Protein is mainly ingested through concentrates and later in the body used to form structural components of muscles, hoovers, blood etc. Also, proteins in ruminant bodies are used in making enzymes and hormones. Essential amino acids in cattle are; Arginine, Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan and Valine (Knowlton et al., 2003). An overview of protein nutrition of dairy cattle was done by Owens (2014) who have mentioned protein requirement models and systems. The first model is a classical protein requirement model. It was the traditional method of finding out the amino acids that are increasing the milk performances. The performance was measured by giving a single diet with various supplements with various concentrations of protein to a group of animals. When milk performance increases due to addition of a certain protein to a diet, that particular protein is considered as a protein source that is increasing the milk performance. Likewise, if milk performance is decreased when a protein source is removed from the diet, that particular protein is considered as a milk performance improving protein source. During Owens (2014) study, 75 different diets were given to 1151 cows and trial day range was with a range from 1 to 238 with a mean of 85 days. According to the results, milk yield was increased at a low rate. Crude protein amount to achieve the maximum milk yield was 20.6%. However according to the results, milk protein content was decreased when cows have been fed with high protein diets even though milk protein content is considered as an indication of protein adequacy. Other changes occurred due to high protein diets were high serum urea concentrations. An increase in the milk fat concentrations was observed with increased protein content and peaked at 19.4% crude protein. Crude protein digestibility increased linearly and quadratically. The author (Owens, 2014) has also stated that in the early lactation, percentage loss of proteins from the animal through milk is 60% however in late lactation the percentage loss is about 40%.

Second model is a metabolisable protein model, where the nitrogen requirement of the animal is investigated by two major divisions. One is N needed as amino acids for the maintenance and the production and the other one is N required for the growth and the fermentation of the rumen microorganisms. Metabolisable protein amount is considered as the protein supply which is equal to the sum of crude protein synthesised by the rumen microbes and dietary protein which escape the rumen without any microbial degradation. Both will be absorbed at the small intestine later. To evaluate effectiveness of the metabolisable protein model, published data from 21 trials with 37 diets and supplemented with various sources or levels of protein for a total of 117 different diet protein combinations were used. Digested extent of the dietary matter in the rumen was measured in these trials and it was compared with the total digestible nutrients available in the diet. According to the results, the total digestible nutrient amount has no effect on the rumen fermentation extent of organic matter. Therefore estimating microbial protein supply is difficult. Protein escapes from Rumen were also calculated and according to the results, predicted values and the observed values were close enough to make further estimations.

NRC (2001) declared that metabolisable protein (MP) requirement of a cattle for maintenance is dependent on; Body Weight (BW), Dry Matter Intake (DMI), bacterial metabolisable protein and endogenous metabolisable protein. The equation given was:

$$\text{MP (g/day)} = 4.1 \text{x} BW^{0.50} \text{ (kg)} + 0.3 \text{x} BW^{0.60} \text{ (kg)} + \{(\text{DMI (kg) x } 30) - 0.50[(\text{bacteria MP}/0.8) - \text{bacteria MP}]\} + \text{endogenous MP}/0.67$$

The required amount of MP of a pregnant cow is also dependent on the birth weight of the calf, number of days of gestation and how many fetuses carried by the cow. And the net protein requirement for the growth is dependent on average daily weight gain and equivalent shrunk body weight. Eastridge (2006) stated that close-up dry cows have to be fed diets containing 14% to 15% crude protein to balance the ruminal non-degradable protein content. Further, when abundant rumen detergent proteins and crude proteins are given, respectively milk urea nitrogen and blood urea nitrogen levels are increased. Elevated levels of milk urea nitrogen negatively affect fertility.

Minerals

Cows are not able to fulfil their mineral requirement only through forages. Phosphorus is significantly deficient in forages, particularly in mountains and uplands. Calcium to phosphorus ratio in cattle diet is important and imbalances might lead to infertility. Trace elements are also important for fertility (Kavanagh et al., 2016). Another important mineral is magnesium and deficiencies lead to hypomagnesaemia. To supply vital minerals to the cows, supplementation is a must. Vitamin A is one of the most important vitamins in cattle diet. However, all the vitamins required for the metabolism are available in the pasture. Diet can be fortified with vitamins to balance the rations (FAO, 2018). Knowlton et al. (2003) states, deficiencies lead to malfunctions. They are summarized in Table 6.

Table 6 Macro-minerals in cattle nutrition, their functions and deficiency signs

Mineral	Function	Deficiency signs
Calcium	Bone structure, nervous system activity, blood clotting	Rickets, osteoporosis, slow growth
Phosphorus	Bone structure, metabolic functions	Poor reproduction, poor growth
Chorine	Regulation of osmotic pressure, regulation pH in body fluids	Lack of appetite, rapid loss of weight, decline in milk production, uncoordinated movements
Magnesium	Bone structure, nervous system activity	Grass tetany, irritability, convulsions
Potassium	Nervous system activity, regulation of osmotic pressure and pH in body fluids	Emaciation, listlessness, poor performance
Sodium	Nervous system activity, regulation of osmotic pressure and pH in body fluids	Abnormal eating behaviour, urine licking
Sulphur	Acid base balance, ruminal growth	Poor appetite, unthrifty appearance, dullness of hair coat and hair loss

Fat

Eastridge (2006) proclaimed that mixed responses were observed when lactating cows were given with sugar supplements. This study states that in summer, maintaining the body temperature of the animal is affecting the performance of the animal. Elevation of body temperature negatively affects the milk performance. Therefore fat supplementation should be high in summer. Thereby, cows can produce more energy to increase milk performance without increasing the body temperature. However dry matter intake will be reduced if the diet contains excessive amounts of saturated fat due to the retention of fat in the rumen. Most of the ingested fat is used to produce methane in the rumen and rumen microorganisms do not use ingested fat as an energy source. The utilizable form of fatty acids are supplied to the cow by the rumen microorganisms. Triglycerides contained in the diet mostly undergo lipolysis in the rumen. Majority of the unsaturated fatty acids are being bio-hydrogenated by bacteria. Biohydrogenation amount depends on the rate of passage, rumen pH, chemical form of the fatty acid and the particle size of the fat source. Commercially available fats are inert in the rumen and less bio-hydrogenated than the natural fat sources. However, most of the commercially available fat sources are less palatable (Eastridge, 2006).

Vitamins

Knowlton et al. (2003) reported that many roles are being played by vitamins, they are; absorption and metabolism of carbohydrates, proteins, fats and minerals, brain functions, helping immunity, fertility, proper digestion.

Feeding systems and feeding frequency

To help and guide dairy farmers and nutritionists about formulating rations and feeding livestock, feeding standards have been declared since the late 1800s. Time to time, these standards are updated according to the most current research information and innovations (Harris, 1992). To increase the milk production per cow, most of the leading countries in dairy farming have moved to the high input/ high output systems. Providing Total Mixed Ration (TMR) diets that are based on cattle concentrates is one of the most important steps of this high input/ high output system. This method was initiated by most of the North American and European countries. Opposite method of a high input/ high output system is allowing cows to feed on pasture. However, countries such as New Zealand and Ireland are still using the ‘feed on pasture’ method and yet these countries remain at the top dairy farming countries in the world. Yet, these countries are able to provide roughly half of the milk production by using Holstein strains compared to the countries which are using high input/high output systems, while exhibiting cows with high Body Conditions Scores (BCS) and 50 kg to 100 kg lighter cows. “Feed on pasture system” is facilitating animals that are free from hunger by providing an excessive amount of forage. Even though animals can stay free from hunger through the feed on pasture method, freedom from hunger cannot stand alone to maximise the milk yield as the high input/ high output method. However, it guarantees lighter weight and medium milk producing cows with high fertility potential. This system is not appropriate for the heavy weight, high milk producing cows. On the other hand no access to the pasture is considered as a practice against animal welfare. Also, currently 80% to 85% of the dairy farms are using high input/ high output indoor systems. Only 15% to 20% of the farms are using the feed on pasture method. This study reveals that farms which are conducting the pasture method are also providing high energy rich concentrates to cattle to increase their milk yield (Knaus, 2016).

A study conducted by Delahoy et al. (2016) has found that factors such as quality, quantity, nutrient and energy requirement of the pasture available for the animal can change constantly. Therefore it is a challenge for the farmers who use fed on pasture methods. Kolver et al. (1998) states that to manage pasture fed methods, farmers have to have experience and computing skills to calculate the changes of pasture quality, quantity and energy requirement. McCarthy et al. (2011) reveals that attainable milk yield per hectare (ha) of a given pasture is dependent on nitrogen fertilization, lactation stage, concentrate supplementation and stocking density (cows ha^{-1}). A study conducted to investigate the effect of pasture allowance and daily supplementation on grazing behaviour, feed intake and milk performance of high yielding Holstein cows (Bargo et al., 2002) declares that average grazing time of cows that are pasture fed and cows supplemented; are respectively 617 min day^{-1} and 528 min day^{-1}. Higher biting rate was observed in pasture fed cows, resulting in an average biting rate of 348000 bites per day. Also high DMI is reported in both high pasture only fed and low pasture only fed cows compared to high and low pasture allowance and supplemented cows. High milk productions were observed in both supplemented high and low pasture allowance cows. The study concluded that milk response is greater at low pasture allowance cows.

There are two methods of providing cattle concentrates to cows. In one method, concentrates are provided separately and in the second method concentrates are provided as Total Mixed Rations (TMR). Mostly concentrates are being provided to the cows twice a day. However, TMR became more popular than providing concentrates separately (Istasse et al., 1986). Two experiments have been conducted in this study. Experiment 1 has been conducted to investigate the effect of TMR by providing concentration separately on the milk quality, quantity and weight changes of the animal. Here, two portions of cattle concentrates were given (on weight basis 0.65 & 0.40). High milk yields were observed in TMR compared to the separate concentrate given group. The difference was 3.9kg day^{-1}. Also average milk yield was 2.4 kg day^{-1} higher in the 0.65 concentrate portion given group. However high milk fat concentrations were observed in the group which has been provided with low portions of concentrates compared to that of the high portion group. No significant difference in the milk solid concentration has been observed in both the high and low concentrate fed groups. Average protein concentration value was 125.6 g kg^{-1}. Same effect has been noticed regarding the protein concentrations of the milk with an average protein concentration of 32.6 g kg^{-1}. However, both high and low portion concentrates given TMR groups have a significantly higher protein concentration than the groups which are given concentrate separately. Average live weight change of the study was reported as a loss of 0.28 kg day^{-1} and TMR given groups have a significantly low live weight loss than the groups which are being provided concentrates separately. Therefore, the study concluded that TMR can cause a significant difference in milk quality, quantity and live weight change of the cows than the feeding concentration separately. A similar conclusion was stated in another study, that the milk fat concentration is higher in cows receiving a TMR compared to the separately concentrate fed cows (Kennelly, 1996). In a parallel study, Kolver and Muller (1998) have investigated that the milk fat percentage of high producing Holstein cows who have been fed TMR have a significantly higher protein concentration value than the cows who have been fed concentrate separately.

According to Istasse et al. (1986), during the experiment 2; thirty-two Holstein Friesian cows were used as 4 groups each containing 8 cows. Cows were grouped according to milk yielding potential and parity. Two types of concentrates were used in the experiment to determine the effect on milk quality, quantity and live weight change. Used cattle concentrate portion was 0.60 and 0.40 (on weight basis) ammonia treated straw. TMR and separate concentrates were provided to the group's two times a day. Rolled barley and sugar beet pulp were used as the two concentrates. As in the experiment 1, TMR given groups showed higher milk yields than that of the separately concentrate fed groups. Milk yield of the sugar beet pulp given groups had a slightly higher milk yield than the groups which have been provided rolled barley. Also the milk fat concentration was slightly higher in the separate concentrate fed groups and the value was high for the sugar beet pulp given groups, however, the difference is not significant. However protein concentration had no effect on any of the groups. A 0.31kg day^{-1} of a live weight loss has been reported throughout the experiment. Weight loss was significantly lower for the groups which have provided TMR. The study concluded that there is no significant effect on milk quality and quantity by providing sugar beet pulp or rolled barley.

However, some studies have suggested that the milk component can be improved by feeding the cows with TMR twice a day (Hutjens, 1996). Main three aspects of improving milk composition are nutrition and management, cow genetics and dairy processing methods (Walker et al., 2004). More studies have reported milk composition can be altered by feeding the cow with different grains. (Casper et al., 1990) declared that the milk yield of cows fed with corn grain is higher than the cows fed with barley. Also, high moist corn has a greater impact on milk yield than the dry ground corn (Wilkerson et al., 1997). However, some studies show that the type of grain or the amount of ruminal starch does not have an effect on milk yield (Slots et al., 2009). Ferland et al. (2018) has investigated the effect of feeding systems and grain sources on lactation characteristics and milk components of dairy cattle. The study has been conducted for about 5 years. There, three different grain sources and a compound concentrate were used as the energy sources. Those grain sources are barley, corn grain and high-moist corn. Two feedings used were TMR and component feeding system (feeding concentrates and forage separately). Concentrates or grains were measured in scoops and in TMR it was measured by the automatic feeder with a 0.5 kg day^{-1}. Forages were fed on group basis and a group contained 15 cows. Cows were separated into three main groups according to the level of lactation, milk yield potential and parity. According to the results, increments in milk yields were observed in TMR fed first and third groups. Additional milk yield is varying from 697 kg for the first-parity cows to 561 kg for third-parity cows and the corresponding increment percentage was 8.6% and 5.3%. However milk yield peaks were high in TMR fed cows compared to component fed cows. Even though the milk yield of TMR fed cows was high, both feeding systems showed a similar decrease. Further, the milk yield maintained at higher levels until the end of the lactation. Moreover, the TMR feeding system resulted in high fat, protein and lactose yields ranging from 4.7% to 10.8%. According to Ferland et al. (2018) higher milk yields lead to higher milk component yields. Even though both TMR and component fed systems could result in high protein yields, curve characteristics are different over the lactation period of yield. Protein curve of TMR fed cows is following the same pattern of the milk yield curve and reaches the peak at around 60th day. Meanwhile, the protein yield curve of component fed cows has continuously decreased over the entire lactation. According to the results, the study has concluded that the TMR feeding system supports high protein synthesis and secretory activity during early lactations. Also, the authors claimed that milk production persistence is better particularly in first lactating cows compared to the cows in the component fed system. Higher daily lactose yields were reported in early lactation for TMR fed cows than component fed cows and the overall lactose yield is higher in TMR fed cows. Milk Urea Nitrogen (MUN) of the TMR fed cows was comparatively lower than the compound fed cows. When comparing milk components with respective to concentrate variety, highest milk yield was observed with high moist corn and the yield has decreased from corn grain to commercial concentrate to barley. Corn fed cows produced a significantly high milk amount with every delivery compared to barley fed cows. There was no significant difference in fat concentration with respect to the concentrate type. However, barley and corn fed cows' milk fat concentration is generally higher than the commercial concentrate fed cows. There is no significant difference in corn grain fed and high-moist corn fed cows' milk fat concentration. MUN concentration was significantly lower in cows fed high-moist corn and corn grain than barley and commercial concentrates. Same results were found by Burkholder et al. (2004). Concentrates which led the milk to the highest level of MUN had a high Crude Protein (CP) content. Grains which had the highest amount of CP were barley followed by corn grain and high-moist corn.

Kaufmann (1976) stated that through increasing feeding frequency from twice to six times a day, higher rumen fluid pH, reduction in pH fluctuation, improvements in the acetate/propionate ratio and a higher milk-fat can be obtained. However a commonly used strategy among farmers to reduce milk-fat is feeding hay in prior to grains. Macleod et al. (1994) have conducted a study to determine the effect of feeding frequency of concentrate and feeding sequence of hay on eating behaviour, ruminal environment and milk production in dairy cows. There was no significant effect on the milk-fat content by feeding frequency and sequence of feeding hay and concentrate in this study. The protein content of the milk also did not have any effect from the study. The mean proportional increase of milk protein concentrate was 1 – 6 (±1.1) %. Live weight change was observed throughout the 4 weeks period and there was no significant effect reported in live weight change according to the feeding frequency of concentrate and feeding sequence of hay. However, out of 29 experiments, a significant increase in milk yield was observed only in 4 experiments with respect to the feeding frequency. But in almost 24 experiments there was no significant effect on milk production by the feeding frequency. One experiment has shown that there is a significantly negative effect on milk yield by the feeding frequency. Out of 34 experiments, only seven experiments showed a significant effect of feeding frequency on the increasing milk fat concentration and in 27 experiments there was no such significant effect. However, the calculated correlation between the proportional response of milk yield and the milk fat concentration was small and negative. There was no effect on milk lactose concentration by the feeding frequency in any of the experiments.

A recent study by Ledinek et al. (2018) stated that dairy cattle supplementation enhances DMI of Holstein Friesian cows kept on pasture. Knaus (2016) declared that to fulfil high energy demand and to reduce negative energy balance, high-input/ high-output dairy farms which are located in permanent grasslands also have to purchase high energy concentrates. Allen et al. (2014) proclaimed that feed intake of a cow is controlled by four main signals. Origins of the signals are physical, metabolic and endocrine as well as by the environment and management.

Feed types

Isher et al. (1914) proclaimed cattle concentrates are being given to cattle mainly to provide the energy needed for their metabolism and to overcome any deficiencies that cannot be overcome by the provided forages. Mainly cattle concentrates are high-energy, low-fibre feeds which can be low, medium or high in proteins. Through concentrates, cattle can obtain energy which are form Non-Fibre Carbohydrates (NFC) and fat, Protein sources such as Crude Protein (CP), Degradable Intake Protein (DIP), Soluble Protein (SP) and Undegradable Intake Proteins (UIP), fibre sources which are Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF), macro minerals such as calcium, phosphorus, magnesium, potassium, sodium, sulphur, chloride etc., micro-minerals such as manganese, copper, zinc, iron, selenium, cobalt, iodine, etc. and fat-soluble Vitamins which are Vitamin A, Vitamin D, Vitamin E and Vitamin K. Therefore concentrates can be considered as carriers of various nutrients. Although it carries a majority of the nutrients, palatability of the product is important to obtain the required levels of feed intake. Therefore the processing method and the particle size is important in feeding.

The same document declares that ingredients that are used to process cattle concentrates can be divided into three categories. They are cereal grains, protein sources and by-products feed.

Common cereal varieties which are used to make concentrates are barley, corn, milo, oats, rye triticale and wheat. General characteristics of these grains are high in energy and low in fibre content, comparatively high levels of phosphorus and low in calcium. Energy is available in the grains as fats, starches and sugars. Eighty percent of the NFC is available as starches. Bioavailability and the digestion rate of the starch vary according to the grain variety and the processing method. Ruminal digestion rate and the degrading amount of the concentrate depend according to the processing method of the concentrate which is consisting of grains. According to the extent of the milling process, digestion rate differs. Finely ground grains have higher ruminal microorganism degrading rates than the grains which are ground coarsely. The reason is the higher surface area of finely ground grains which provide a higher surface area for the microorganism to attach. Therefore the undegradable amount will be less and if so that portion will be digested by the enzymes available in the small intestine. Also in the rumen high-moisture grains ferment more rapidly than the dry grains. Heat treatments such as steaming are another way to increase the digestibility of grains. Steaming causes gelatinisation of starches and facilitates more digestibility.

Protein sources can be divided into two main classes; animal sources and plant sources. Mostly cows are being fed high protein concentrates; therefore the protein quality of the source is highly concerned prior to processing. Protein quality depends on the type of the sources, amount and the ratio of peptides and amino acids. Some Nitrogen sources such as urea are added to the concentrates. Although they are not protein, ruminal bacteria have the ability to convert them to proteins in the rumen. Urea is functioning well in concentrate mixture, especially when plant protein varieties are being added and the soluble protein content needs to be increased. Also, addition of urea to concentrates is cost effective. Even though there are a lot of protein sources available, the limitation is the palatability of the source to the cow. By-product feeds are mostly added as the secondary materials. Commonly used by-product feeds are cereal-derived products during the milling processes. According to the characteristics of the by-product variety, it is being used for the ration formulation. Sources which contain high-fat content can be used for high energy concentrates or they can be used to balance the energy levels of concentrates. When a by-product is being used as a protein source, protein quality and protein levels have to be concerned. According to the NDF content, they can be used to balance the NDF levels of the product. Some of the by-product feeds add high levels of minerals and vitamins to the final product.

Isher et al. (1914) also discussed the preparation methods of concentrates. According to the characteristics of the grain source, preparation can be divided into two methods. The two sources are dry grains and high moisture grains. When considering dry grains, the particle size is one of the major facts. According to the particle size of the grains digestion rate and the amount varies. Therefore dry grains must be ground through a 1/2 to 5/8 inch screen. Digestibility of the steamed rolled, steam flaked, crimped or steamed grains are equal to the digestibility of the properly ground grains. However final concentrate should not contain more than 35% to 40% heat treated concentrates to avoid milk fat test depression. If the proper particle size can be obtained through mechanically crimped, rolled or flaked grains, their digestibility can be considered as equal to the proper ground grains. If the pelleting process is undergone, the particle size must be 3/32 inch screen or finer, high starch ingredients must be limited to 34% to 40%, a fibre source must be used prior obtaining the hardness and binding agents must be added. According to the age of the cow types, the particle size of the dry grain concentrates can be adjusted. Young cattle under four to six months can be fed concentrates with high particle size due to their adequate amount of chewing time. High moisture grains, on the other hand, need proper preparation due to two main reasons. They are; to prevent sorting and to increase the digestibility. If the grains are ensiled, they can be prepared more coarsely than dried grains due to the high digestibility and solubility.

Isher et al. (1914) also has mentioned the appropriate use of feed ingredients. The sources which consist of high nutrition are discussed. Ingredients with higher CP are soybean meal, corn gluten meal, urea, raw soybeans, canola meal, cottonseed meal, heat treated soybean. Ingredients high in UIP are blood meal, corn gluten meal, fish meal, animal protein blends, wet and dry brewers grain, distillers grain, heat treated soybean. Ingredients with a higher SP are corn gluten feed, whole cottonseed, wheat midds, raw soybeans and urea. High NFC ingredients are bakery products, barley, milo, rye, corn, hominy, oats and wheat. High-fat sources are chocolate, bakery waste products, raw soybeans, whole cottonseed, candy waste products, tallow, heat treated soybeans. Sources which are high in NDF are corn gluten feed, distillers' grain, wheat midds, wet and dry brewers' grain, whole cottonseed and soyhulls. Cows which consume a diet containing corn silage and hay must be supplemented with sources which contains SP. A diet which contains ensiled hay crop, corn silage or hay must be supplemented with sources, which contains high UIP.

Coconut oil cake is one of the commonly used cattle concentrate type in Sri Lanka and comes under the by-product feed which is a by-product of the coconut oil milling process. Coconut oil cake can be obtained through any type of coconut oil milling processes such as virgin coconut oil, extra virgin coconut oil etc. According to a study conducted by Yalegama et al. (2013) declare the chemical and functional properties of fibre concentrates obtained from by-products of coconut kernel. Under that study, chemical and functional properties of virgin coconut oil residue (coconut oil cake of virgin coconut oil milling) were tested. Fully mature coconuts were used for the study. White coconut kernels were removed from the shell and dried in a cabinet dryer (Wessberg, Martin, Germany) at 70 °C until the moisture content reduced to 2 – 3%. Those kernels were introduced for the virgin coconut oil extractor (Cold press; Komet DD85, Germany) and the process was done at 65 °C. The residue was ground by domestic grinder (LG, Korea) to obtain coconut flour from virgin coconut oil residue. Association of Official Analytical Chemists International (1995) methods were used to analyse the moisture, fat, protein and crude fibre contents. To determine the sugar content Dubois et al. (1956) method was followed. Metal iron concentrations were determined through an atomic absorption spectrometer (GBC 904AA, Australia) with relevant hollow cathode lamps. Composition according to the

analysis was moisture 4.2±0.4%, fat 9.2±0.2%, protein 12.6±0.3%, sugar 13.7±0.4%, ash 8.2±0.2%, crude fibre 13.0±0.3%, carbohydrates 39.1±1.8%. Metal iron concentrations were Fe (II) 227±12 ppm, Cu(II) 34.2±2.2 ppm, Mn(II) 70.1±2.1 ppm and Zn(II) 92.2±2.3 ppm.
A parallel study conducted by Rodsamran et al. (2018) declared that nutrient composition of coconut oil cake as dry matter 95.61±0.32%, ash 2.43±0.13%, oil 16.08±1.35%, protein 8.58±0.08% and carbohydrate 72.91±1.32%. According to Kavanagh et al. (2016) cattle concentrate types can be divided into two main categories. They are energy feeds and protein feeds. Both types have advantages and disadvantages. Main energy feeds are:

- Barley; the starch composition is high. High proportions in grazing concentrate mixes are not encouraged. Higher feeding rates might lead to acidosis
- Wheat; high in starch composition and digestibility is higher. Risk of acidosis is higher compared to barley and maize.
- Maize grains; the starch composition is high but slowly digestible. Risk of acidosis is less compared to barley and wheat.
- Citrus pulp; Quality sources of digestible fibre and sugars which are suitable for cows whose feed is based on grass.
- Beet pulp; Quality sources of digestible fibre and sugars which are suitable for cows whose feed is based on grass..
- Soya hulls; Quality sources of digestible fibre and sugars. Energy content is comparatively moderate. Suitable for cows whose feed is based on grass.
- Wheat feed (By-product wheat milling); low energy levels.
- Soybean meal; best quality proteins are available compared to the other energy feeds. High by-pass proteins.
- Molasses; mainly used as a binding agent in pellets to increase the palatability and to reduce dust, rather than as a direct concentrate.

Better to include the above pros and cons in a table other than writing in point form.
Main protein feeds are:

- Maize distillers grains; Protein content is moderate and the energy content is higher compared to other protein feeds. Shows high oil content. Milk fat content can be affected. Unprotected fat in the diet increases to 6%.
- Maize gluten feed; Energy content and protein content are moderate.
- Rapeseed meal; protein content is high and quality sources of rumen degradable proteins. High inclusion rates lead to palatability problems.
- Palm kernel meal; Energy content is low.
- Sunflower meal; Low in energy content and protein content is high. Protein quality is comparatively lower.

Better to include the above pros and cons in a table other than writing in point form.

Cost for dairy cattle concentrates and feed

Dairy cattle concentrates are one of the main aspects of dairy farming. One of the main concerns of dairy farmers is the cost of dairy cattle concentrates. According to the concentrate type cost of the product and the milk quality and quantity may vary. Ishler et al. (1914) declared that purchased feed might represent 40 to 55% of the total expenses on farms. For that purchased feed, a limited amount of purchased forage can also be included. According to that statement, dairy cattle concentrates can be considered as one of the driving forces of dairy farming.

Kavanagh (2016) have proclaimed methods to optimise the cost of concentrates. Some of them are suitable for countries that face seasonal changes. To get ready for the gaps in grass supply due to the seasonal changes, balancing the diet that is being given for the animals is done. Normally in the breeding season, grass supply can be limited or the grazing conditions can be poor. Therefore animals must be supplemented to fulfil the nutritional gap. When the grazing conditions or the grass supply is in good condition, animals can be given less concentrates. For these changes farmers must be ready and prepared. For example; in the autumn, high quality surplus bales and/or concentrates can be fed to the animals to overcome the grass supply gaps. Another suggestion to optimise the concentrate cost is giving different types of concentrate types to animals to fulfil various types of nutritional requirements. For example; trace elements are important for fertility. Rather than feeding the animal with large portions of concentrates which are having fewer amounts of trace elements, feeding the animal with less amount of a special concentrate that contains high levels of trace elements is cost effective. Further, sudden drops of milk quality such as protein and fat concentrations, occur most of the time due to the poor grass quality. Therefore feeding larger portions of concentrates to call upon such quality losses is a disadvantage. Most economical way to overcome them is by providing high quality grass. Providing a mix feed at the parlour is one of the least labour intensive methods. Labour cost and fixed cost will be high due to providing alternative forages such as maize silage. Furthermore, when weighing up feed everyday will add more labour cost. When buying a concentrate, nutritional requirements of the animal should be known. Calorie value is one of the most valuable nutrient aspects and therefore, buying decisions must give more attention towards energy content even though protein is important in cattle diets. Main consideration should be the cost reduction while providing the appropriate nutrition to the cow. Sometimes most expensive concentrates may not provide proper nutrition in some cases.

Dekkers et al. (1998) have conducted a study to determine the economic aspects of persistency of lactation in dairy cattle. Generally, cattle breeds who are showing an even milk yield throughout the lactation period; are able to maintain the lactation curve constantly by increasing the forage fraction in diets rather than increasing the expensive concentrates to provide energy requirements. In the 1st, 2nd and the 3rd month of the study, dry matter intake was reduced 15%, 7.5% and 2.5 % respectively. Another model was run by reducing 5% dry matter intake capacity to determine the impact of dry matter intake capacity. According to the results, profit returns from milk were independent of feed intake capacity. Average feed cost per lactation increased by 12% to 16% due to the reduction of dry matter intake capacity by 5%. The main reason was identified as the expensive, energy dense rations used to meet energy demands.

A comparison study was conducted by Sölkner et al. (1987) to determine the different measures of persistency with special respect to variation of the test-day yields. Simmental cows were used for the study and 655 lactation records of cows from 10 herds were taken and each day feeding records were taken. According to the milk yields, cows were divided into two categories which are high and low persistency. Herds were given their concentrate rations according to their test-day milk yields. Milk yield, milk fat, milk protein contents and concentrate consumption during different test-days were analysed using a least square model which also included fixed effect of persistency group, number of lactation, month of calving, linear and quadratic regression for days open and lactation milk yield of the cow. According to the results after the 305 day lactation period, when the milk yield is adjusted to 5500 kg, the high group had to consume 659 kg of concentrates and the low group had to consume 820 kg of concentrates. Therefore the study concluded that the impact of persistency on profitability of milk production is high". Greatest influence on the profitability of dairy farms mainly depends on milk yield per cow and the cost of feed to produce milk (Harris, 1992).

Conclusion

Global dairy cattle sector improves year by year due to the advances of its related sectors. However, considering developing countries; dairy cattle sector is yet to be developed. Main nutritional components of cattle feed are: water, energy, vitamins and minerals. According to several studies, limiting nutritional components for dairy production are energy and protein. Quite a few studies have revealed that the nutritional requirements of animals differ according to the type of animal, milk yield, feeding type, grazing quality, lactation period etc. Through current findings; feed type can be selected according to the animal type, condition and feeding method. Disadvantages such as acidosis have to be avoided. Most of the studies reveal that the TMR positively affects milk properties rather than feeding the concentrates separately. Profitability of dairy farms depends on milk yield and the cost of feed for animals.

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