Factors Affecting Milk Yield

Under normal situations, milk production increases during the first six weeks of lactation and then gradually decreases. The actual amount of milk produced during the lactation period is affected by several factors:

1. Breed
2. Parity
3. Season of calving
4. Geographic region
5. Management factors (nutrition, frequency of milking)

Breed

In North America, the Holstein cow has the highest volume of milk production and the highest total production of all major milk components (i.e. fat, protein and lactose). However, there are a lot of variations in milk yield and composition between individuals within a certain dairy breed.

Breed	Yield			Fat yield			Protein yield	
	Mean	SD		Mean	SD		Mean	SD
Holstein	7073	1425		264	58		226	47
Ayrshire	5247	1061		211	45		177	38
Jersey	4444	1130		230	62		175	44
Brown Swiss	5812	1421		244	63		210	52
Guernsey	4809	1095		236	56		177	42

Dry period

Dairy cows are usually dried-off for two months prior to the next calving. This rest period is necessary to maximize milk production in subsequent lactation. Milk yield is usually reduced when the dry period is less than 40-60 days (25-40% less milk). Dry period longer than 60 days in length does not result in a significant increase in milk production. Long dry periods decrease the average annual production of the cow by extending the calving interval beyond the normal 13-14 month interval and causing a decrease in the lifetime production of the dairy cow.

Part of the dry period effect is related to body condition of the cow at calving. Cows in good body condition at calving produce higher milk yield during the following lactation than in cows in thin body condition at calving.

Age and body weight at calving

The amount of milk produced by the cow increases with advancing lactations (age). This is due in part to an increase in body weight, which results in a larger digestive system and a larger mammary gland for the secretion of milk. Another reason for increased milk production with age is due to the effects of recurring pregnancies and lactations. Data on milk production with cows suggest that 20% of the increase in milk production is due to increased body weight and 80% to the effects of recurring pregnancy and lactations. Recurring pregnancies and lactation can result in increases of 30% in milk production from the first to the fifth lactation.

Lactation number

Milk production increases with lactation number and is maximized in the fourth or the fifth lactation. This is a result of the increasing development and size of the udder and the increasing body size over that of the first lactation animal. The expected mature yield (mature equivalent) of a primiparous cow calving at two years of age can be estimated by multiplying yield of first lactation by 1.3.

Pregnancy

Pregnancy has an inhibitory effect on milk yield. Most of the reduction in milk yield occurs after the fifth month of pregnancy. By the 8th month of pregnancy, milk yield may be 20% less for that month compared with non-pregnant cow. The inhibitory effect of pregnancy is not likely due to fetal requirement, which does not increase considerably until the last two months of pregnancy. It is believed that the increase in estrogen and progesterone level as pregnancy progresses, inhibits milk secretion. Some studies with mice indicated that progesterone inhibits the activity of α-lactalbumin.

Season of calving

The effect of season of calving on milk yield is confounded by breed, the stage of lactation, and climatic condition. Cows calving in late fall to spring produce more milk (up to 8% more) than cows calving in the summer. This is likely due to an interaction between day light and ambient temperature. Seasonal differences have become less significant because of better feeding and management of the dairy cow.

Ambient temperature

The effect of ambient temperature on milk yield is dependent upon the breed. Holsteins and the other larger breeds are more tolerant to lower temperatures, whereas the smaller breeds particularly the Jersey, are much more tolerant to high temperatures. The optimum temperature for the Holstein cow is about 10 °C. Milk production declines when environmental temperature exceeds 27 °C. The reduction in milk yield is largely due to drop in feed intake. High temperature affect high producing cows more than low producers and it is particularly harmful during the peak of lactation.

Disease

The main disease that affect milk yield of dairy cows is mastitis. It impairs the ability of secretory tissue synthesize milk components and destroys the secretory tissues and consequently lowering milk yield. A decrease in production persists after the disappearance of the clinical signs of mastitis due to a destruction in the secretory tissues.

Management Factors

Feed and water supply

Any restriction in feed or water supply will result in a drop in milk production. The most dramatic effect is brought about by shortage of water as the cow has no means of storing water. Withholding access to water, or insufficient supply of water for few hours will result in a rapid drop in milk yield.

Growth hormones (BST)

There is a positive correlation between milk production of cows and the level of growth hormone in their blood. Growth hormone causes redistribution of nutrient within the cow's body to favor nutrient utilization towards milk production. However, growth hormone is not directly involved in milk secretion process.

Milking intervals

Cows are usually milked at equal intervals (12-h interval for 2 x milking). Cows milked at unequal intervals produce less milk than those milked at equal intervals. The reduction in milk yield is more in high producing cows than in low producing ones. Incomplete milking for several consecutive days can permanently reduce milk yield for the entire lactation. Milking time for most cows is 5-6 minutes per cow.

Milking frequency

Cows are usually milked twice daily. Milking a twice a day yields at least 40% more milk than once a day.. Increasing milking frequency to 3 x day increases milk yield by up to 20% (range 5-20%). The increase is usually highest for first lactation cow and declines as the cow gets older.   The most likely reasons for increased milk production as frequency of milking increases are 1) less intramammary pressure generated with frequent milking, 2) increased stimulation of hormone activity favorable of milk production and 3) less negative feedback on the secretory cells due to the accumulation of milk components. The practice has been implemented to increase milk yield and utilize facilities more efficiently. However, the practice is still being debated. There are several problems associated with 3 x per day milking. It may increase the incidence of mastitis as the cows get exposed to the milking machine more often. The practice is also not recommended for poorly managed herds as existing problems will be aggravated.

Rate of Milk Secretion

The period following milk removal is characterized by low intra-alveolar pressure, which facilitate the transport of newly synthesized milk into the alveolar lumen. As secretion continues between milkings, pressure is exerted on the secretory process by the alveolar luminal contents. When the luminal pressure exceeds the force of secretion as the alveolar enlargement reaches its limit. It is presumed that the distention pressure of the lumen exceeds the strength of the secretory mechanism needed to push the newly formed milk out of the cell. In turn, the buildup of newly formed milk in the cell retards the uptake of milk precursors by chemical feedback mechanism (e.g. FIL) and / or physical factors (e.g. intra-mammary pressure).

The physical factors are a result of the distended alveoli partially displacing all other intramammary compartments, including the blood vessels With restricted blood flow, less nutrients are available for milk production, less hormones are available to drive the mammary synthetic systems, removal of waste products of synthesis is reduced and less oxytocin is available to stimulate the myoepithelial cells.

In Dairy cows, average secretion rate begins to decline after 10 hours since the last milking and secretion stops after 35 hours. The pressure measured in the teat cistern increases in three phases. An initial rapid increase in the pressure caused by the movement of residual milk into the cistern from the alveoli and small ducts. The second, lower phase can be an accumulation of newly synthesized milk that is released into the duct system from the alveolar lumens as they begin to accumulate milk. The third phase is marked by an accelerated pressure increase and probably represent overfilling of alveoli, ducts and gland cisterns.

Residual milk & Available Milk

Residual milk can be defined as the amount of milk left in the udder after milking is completed. About 10-20% of total milk is left in the udder as residual milk. Residual milk can be measured by giving the cow oxytocin and one minute later, milking the cow again. Part of the residual can never be recovered by conventional milking procedures while another fraction can be collected if the amount of residual milk is large due to poor milking procedure. This portion of milk is referred to as available milk. Available milk reflects how well the cow was stimulated for milking. If the cow is not well trained for milking, the amount of available milk uncollected will be great. Large amount of residual milk reduces daily milk production, reduces lactation production and the cow will have fewer days in milk.

Factors Affecting Milk Composition

In cattle, fat is the most variable component while minerals and lactose are the least variable. Milk protein to milk fat ratio ranges from 0.78 to 0.85 depending on breed type. Factors contributing to variations in milk composition include species, genetic variations within species, differences between individuals within a strain and differences in conditions affecting individuals.

Genetic Differences:

Heritability is defined as the ratio of genetic variance to total phenotypic ratio. The concentrations (%) of the three major milk constituents are genetically controlled to a considerable extent. Heritiabilities of fat, protein, and lactose contents average 0.58, 0.49, and 0.5, respectively, while that of milk yield average 0.27. Some milk constituents are strongly correlated

Fat % & protein %	r = 0.45 to 0.55
Fat % & SNF %	r = 0.4
SNF % & protein %	r = 0.81
Milk yield & fat %	r = -0.15 to -0.30
Milk yield & SNF%	r = -0.10
Milk yield & protein %	r = -0.10 to -0.30

The above figures indicate that there is a room to increase milk protein % (by genetic selection) without increasing fat % and that selection for high milk yield alone may reduce milk fat and protein percentages.

Breed Differences

Milk from Holstein cows has a lower milk fat % than milk from Jersey or Guernsey (Table 1). Fat droplets also differ among breeds. Holstein has the smallest fat droplet while Guernsey has the largest. Milk of Jersey cows also has a higher total solids than milk from other dairy cattle breeds. Differences n milk composition among individual with a breed are often larger than differences among breeds. Milk color is also affected by breed type. Milk from Guernsey and Jersey is yellowish in color. This is because these two breeds convert mush less carotene (yellow pigments) to vitamin A than other breeds of dairy cattle.

Table 1. Milk composition of five breeds of dairy cattle.

Breed	Total solids	Fat	Protein	Lactose	Ash
Ayrshire	12.69	3.97	3.26	4.63	0.72
Brown Swiss	12.69	3.80	3.18	4.80	0.72
Guernsey	13.69	4.58	3.49	4.78	0.75
Holstein	11.91	3.56	3.02	4.61	0.3
Jersey	14.15	4.97	3.03	4.70	0.77

Stage of Lactation

A- Colostrum

Colostrum, the first mammary secretion after parturition differs greatly from normal milk (Table 2). Cow's colostrum contains more minerals, protein and less lactose than milk. Fat % is usually higher in colostrum than in milk. Calcium, Mg, P, and Cl are high in colostrums, whereas K is low. Iron is 10-17 times higher in colostrums than in milk. The high levels of Fe are needed for the rapid increase in hemoglobin in the red blood cells of the newborn calf. Colostrum contains 10 times as much vitamin A and 3 times as much vitamin D as milk.

Table 2. Composition of colostrum, transitional milk and milk.

Time after calving	Casein %	Globulin %	Fat %	Lactose %	Ash %	Total solids %
At once	5.00	11.07	6.55	2.90	1.22	26.74
6 hours	3.50	6.60	7.82	3.29	0.97	22.18
12 hours	3.12	2.86	4.10	3.88	0.88	14.84
18 hours	3.00	2.14	4.00	3.75	0.85	13.74
24 hours	2.61	1.91	3.64	3.82	0.85	12.83
36 hours	2.86	1.32	3.58	3.68	0.84	12.10
72 hours	2.77	1.10	3.52	4.41	0.84	12.64
5 days	2.74	1.00	3.55	4.79	0.83	12.91
10 days	2.62	0.68	3.57	4.92	0.82	12.61

The most remarkable difference between colostrums and milk is the extremely high levels of Ig content of colostrum. Mammary secretion gradually changes from colostrums to normal milk within 3-5 postpartum (Figure 1).

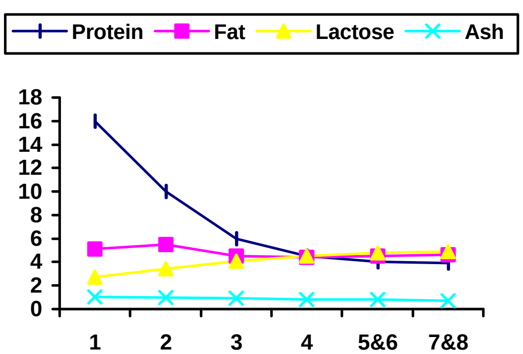

Figure 1. Changes in milk composition at successive milkings

B- Normal Milk

Changes in composition occur during the first few days (see Figure 1) continue but at reduced rate for about 5 weeks of lactation. Fat and protein % then rises gradually and may increase more sharply near the end of lactation (Figure 2). Lactose decreases while mineral concentration increases slightly during that period.

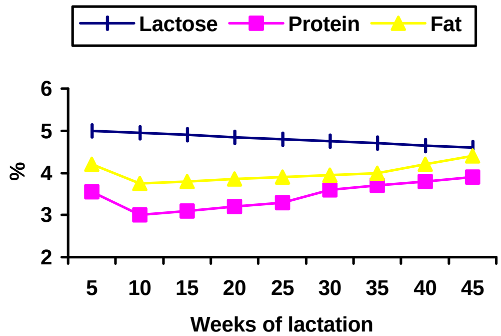

Figure 2. Changes in milk composition as affected by stage of lactation

Change in Milk Composition During Milking

Milk fat % increases continuously during the milking process. First drawn milk may contain only 1-2% fat, whereas, at the end of milking, fat % may be 5-10%. This is because of the tendency of the fat globules to cluster and be trapped in the alveoli. Thus after incomplete milking, milk fat content will be lower than normal. Residual milk (milk remains in the udder after milking) may contain up to 20% fat.

Seasonal Variations

Seasonal variations in milk composition are commonly observed with dairy cattle in temperate regions. In general, milk fat and solid-not-fat percentages are highest in winter and lowest in summer. Milk fat and protein percentages are lower by 0.2-0.4% in summer than winter. Cows calving in the fall or winter produce more fat and solid-not-fat than cows calving in the spring and summer. Considerable variations in milk composition can also be observed in dairy cows raised in pasture.

Diseases

Infection of the udder (mastitis) greatly influences milk composition. Concentrations of fat, solids-not-fat, lactose, casein, β-lactogolbulin and α-lactalbumin are lowered and concentrations of blood of blood serum albumin, Igs, sodium, and chloride are increased. In severe mastitis, the casein content may be below the normal limit of 78% of total protein and the chloride content may rise above the normal maximum level of 0.12%.

Mastitis is also responsible for differences observed in milk composition from different quarters of the udder.

Effects of Nutrition on Milk Composition

Of all milk components, milk fat is the most influenced by dietary manipulations. Most of changes in milk composition due to dietary manipulation are related to changes in ruminal acetate:propionate ratio. Several nutritional factors can influence milk composition. These include plane of nutrition, forage:concentrate ratio, forage quality (e.g. particle size), level and type of dietary fat.

1- **Plane of nutrition:** Underfeeding dairy cows reduces lactose % and increases fat %. Feeding imbalance rations (e.g. low energy:protein ratio) may reduce milk fat and protein percentages.

2- **Forage:concentrate:** As the proportion of the concentrate in the ration increases (above 50-60% of the ration), milk fat % tends to decline. This is mainly because of the lower ruminal production of acetate and butyrate (precursors of milk fatty acid synthesis in the mammary gland) associated with feeding high concentrate diets. The extent of milk fat depression is influenced by other feeding practices such as frequency of feeding and feeding system. Feeding cows less frequently especially if the concentrates are fed separately from the forage results in a reduced ruminal acetate:propionate ratio which in turn can result in reduced milk fat %. In general, the impact of feeding high levels of concentrates on milk fat % will be less where total mix rations are fed and / or if feed is offered three or more times daily.

3- **Forage particle size (forage processing):** Feeding finely chopped forages has a negative impact on milk fat % and may cause milk fat depression syndrome (drop of milk fat % below 3%). Cows fed finely chopped forages spend less time chewing and therefore will produce less saliva. Ruminal pH will drop as less saliva is produced to buffer the acid production in the rumen. As the ruminal pH drops below 6, the activity of the cellulolytic bacteria is reduced and so is the production of acetic and butyric acids (precursors of short chain fatty acid synthesis in the mammary gland.

4- **Level of starch in the ration:** As the level of starch ion the ration increases, the level of acetate produced in the rumen is decreased while that of propionate is increased. This may cause a reduction in milk fat %.

5- **Dietary fat**: Incorporation of fat or oil in dairy cow ration can substantially alter the profile of milk fatty acids. The effect of supplemented fat on milk fat % depends on the type of supplemental fat. Feeding polyunsaturated fat (susceptible biohydrogenation in the rumen) such as vegetable oils may reduce milk fat % whereas feeding protected fat tend to increase milk fat %.

Milk fat differs from other sources of animal fat in that it contains significant amount of short chain fatty acids and relatively lower concentrations of long chain fatty acids. The ability of later the composition of milk fat by dietary means arises from the fact that about 50% of the fatty acids present in milk are derived directly from dietary long-chain fatty acids, adipose tissue and microbial synthesis of fatty acids. The second half of milk fatty acids is derived from *de novo* synthesis of short chain fatty acids, the precursor of which are acetate and butyrate. Therefore, milk fat composition is influenced by both end products of ruminal fermentation as well as the supply of dietary long chain fatty acids to the mammary gland.

The extent to which dietary fat alters the fatty acid composition of milk fat is influenced by:

- Fatty acid composition of dietary fat
- The extent of hydrolysis and biohydrogenation of unsaturated fatty acids by ruminal microbes
- Effect of dietary fatty acids on *de novo* synthesis of short chain fatty acids by the mammary gland
- The extent of conversion of saturated fatty acids to mono-unsaturated fatty acids (mainly C18:0 to C18:1) as a result of intestinal and mammary gland desaturase activity.

Feeding oil seeds such as canola, sunflower or flaxseed has been found to reduce the concentrations of short (C4-C10) and medium chain (C16:0) fatty acids and increase the concentrations of C18:0 and C18:1 fatty acids. The inclusion rate of oils seeds in dairy rations is limited by the negative impact of polyunsaturated fatty acids on ruminal fiber digestion. In general, the maximum inclusion level oilseeds should result in 3-4% added dietary fat. At a higher inclusion of fat or if a greater change in the concentration of unsaturated fatty acids in milk is desired, some form of protection (e.g. heat treatment) should be applied to avoid negative effects on fiber digestion in the rumen.