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Elevated Free Fatty Acids (FFAs) in Bulk Tank Milk

Introduction

Elevated free fatty acids (FFAs) in bulk tank milk impair milk quality, cow health and consumer satisfaction of dairy products. They have become a large concern in many parts of Canada. Reducing the amount of FFAs in milk beginning at the farm is a way that Canadian dairy farmers can help to combat this issue and contribute to sustainability of the dairy industry. This document summarizes the current knowledge about risk factors for increased FFAs and presents some actions for consideration that may help to decrease FFAs in milk.

What are FFAs?

Fatty acids are the building blocks of bovine milk fat. The primary component of milk fat is a triglyceride molecule which is composed of a glycerol backbone with 3 fatty acids attached (Jensen et al., 1991). Triglycerides maintain their structure in milk, for the most part, because they are protected inside a milk fat globule (MFG) membrane (Wiking et al., 2019). The membrane functions to inhibit lipoprotein lipase (LPL), an enzyme that breaks down fat, from targeting the triglycerides and separating them into their components (Wiking et al., 2019).

The MFG membrane can, however, be destroyed through the process of lipolysis. *Lipolysis* is the term for fat catabolism (breakdown) into free fatty acids and occurs in 2 ways: induced and spontaneous. *Induced lipolysis* is the result of the milk fat globule becoming physically or chemically damaged. *Spontaneous lipolysis* occurs in susceptible milk with weak MFG membranes (the result of individual cow factors) regardless of chemical or physical stress on the milk. Both forms of lipolysis result in the splitting of triglyceride molecules into their components of glycerol and fatty acids. When fatty acids are unbound from the glycerol molecule, they are referred to as FFAs.

Low Levels of milk FFAs are Normal

Lipolysis is a naturally occurring process, so all milk is expected to have low levels of FFAs. These normal levels range from **0.5 to 1.2 mmol/100g** of fat, which accounts for only 0.1% of milk fat (Månsson, 2008). While there is some disagreement in the literature, it is generally held that FFA levels that exceed the 1.2 mmol/100g fat threshold are the results of excessive chemical and/or physical stress to the milk fat globule membrane. These levels can have some degree of impact on the sensory properties of the milk, such as taste and smell, leading to quality concerns (Wiking et al., 2017).

How do FFAs Impair Milk Quality?

High concentrations of FFAs, in particular short chain FFAs, are associated with undesirable milk characteristics such as off-flavour, rancidity, reduced frothing ability, inhibited milk fermentation and impaired cheese coagulation (Hanuš et al., 2008). Elevated FFAs cause these unfavourable milk properties by lowering the milk surface tension and reducing or inhibiting fermentation (Kamath et al., 2008).

Risk Factors Associated with Elevated FFAs

FFA research has been extensive in Europe but lacking in Canada. European studies indicate that FFAs are associated with a wide range of factors that are believed to induce stress on milk fat. Since many of these relationships are derived from observational studies, the relative importance of these factors in increasing FFA's is not clear. These factors include individual cow characteristics, herd management procedures, ration composition, milking system layout, pipeline configuration, milk pumping and milk storage.

Milking system: There is a consistent association between elevated FFAs and automatic milking systems (AMS). Studies in Europe and Canada are consistently reporting higher average FFA levels on farms milking with AMS and in tie-stalls, compared to conventional parlors. This finding is likely due to some combination of narrow or oversized pipeline diameter, increased vacuum/air admission, long pipeline lengths, high milk lines, and increased milking frequency (low milk yields and increased milking failures lead to increased air to milk ratio in the system), all of which can induce additional stress on the milk fat globule membrane. It is significant to note that not all AMS farms have high FFA, and it will be important to investigate which attributes of the various AMS systems and models are most closely associated with elevated FFA.

Considerations:

- **For AMS, set a maximum number of 3 visits a day for low yielding and later lactation cows**

Pipelines: Reduced laminar flow of milk through pipelines can result from many factors including smaller or oversized pipeline diameter, a steep pipeline slope, many milking units per slope, a high individual cow peak milk flow rate, and air lost during unit attachment. All can contribute to more physical contact between the milk fat globule membrane and the pipe wall, resulting in MFG breakage (Wiking et al., 2019). In addition, the frequency and angle of pipeline turns will impact fluid dynamics and the laminar flow of milk. Pipelines that are longer or have more vertical lift require greater air admission to allow milk to reach the bulk tank. All systems can experience air leaks throughout the milking system with can increase vacuum levels and thus FFAs. These leaks can occur in the milk inlets, at milking units or at receiver groups. This additional air admission can disrupt the MFG membrane and increase FFA levels.

Considerations:

- **Avoid high milk lines and unnecessary turns and distances of the pipeline**
- **Provide a direct and simple route for milk to flow from the cow to the bulk tank**
- **Avoid short 90-degree elbows in the pipeline when possible. Aim for longer, more gradual turns with an increased angle**
- **Increase pipeline diameter or milk fewer cows on the same line at once (tie stall and parlour systems)**
- **Pipelines should have a gradual slope towards the receiving jar to promote milk flow to reduce vacuum level requirements**
- **Limit air admission into the system through leaking inlet gaskets and /or improper milking unit attachment. Frequent servicing of milking equipment can help to check vacuum levels.**

Receiving Jar and Pump: Excessive pumping of the milk results in physical stress to the MFG membrane (Wiking et al., 2019). Milk that enters small receiving jars will be pumped out at a greater frequency and may cause more turbulent milk action. Different pumps can also affect MFG membrane integrity. A positive displacement/bladder pump has been associated with increased milk turbulence compared to the common centrifugal pump (Wiking et al., 2019).

Considerations:

- **For AMS, choose systems that have a centrifugal pump**
- **Place receiving jar and pump close to the bulk tank to decrease milk travel distance during high velocity pumping**

Cooling: Milk cooled before entering the bulk tank reduces the growth of psychrotrophic bacteria, which produce enzymes that will break down triglycerides (Deeth, 2011). Combining this bacterial breakdown with the normal breakdown described previously may elevate FFAs (Deeth, 2011). Reducing the opportunity for bacterial growth through pre-cooling may result in lower FFAs. In addition, cooling milk prior to reaching the bulk tank will reduce the cooling demand in the bulk tank and thus the amount of milk agitation that needs to occur as the tank fills.

Considerations:

- **Install a plate cooler to be inserted between the receiving jar and bulk tank if slow cooling of milk in the tank is an issue**

Bulk Tank: Cooling and agitation levels and settings can impact the MFG membrane integrity. Milk that is warmer is susceptible to increased microbial lipolysis and is agitated more to reach the acceptable temperature in the tank. Increased agitation (either through increased duration or frequency) can contribute to physical stress of the milk fat globule membrane, resulting in breakage. Insufficient or slow bulk tank cooling can increase induced lipolysis activity, but cooling the milk pre-maturely before a sufficient level is in the tank can risk milk freezing and increasing FFA levels. In contrast, cool milk that is added to a hot tank immediately after sanitization can also induce lipolysis.

Considerations:

- **Turn the bulk tank cooler on as soon as milk reaches the agitation paddles in the first milking to reduce the risk of milk freezing (premature cooling) or excessive bacterial lipolysis (late cooling)**
- **Perform a cold acid or sanitize rinse of the bulk tank (or buffer tank) before the first milking to ensure that the tank has completely cooled after the wash cycle**
- **Allow milk to enter the tank through the bottom rather than top to avoid "waterfall" flow into the tank during the first milkings**
- **For AMS, place the buffer tank as close to the bulk tank as possible**

Herd: Herd-level demographic factors influence the level of spontaneous lipolysis occurring in the milk. Breeds with higher milk fat percentage will provide more substrate for LPL activity and tend to have weaker MFG membranes due to the MFG size. This decreased membrane integrity increases spontaneous lipolysis and FFAs. Cows in a later stage of lactation are also likely to produce milk with a weaker MFG membrane as decreased milk yields increase the air to milk ratio, and thus the potential of lipolysis.

Considerations:

- **Avoid stale cows by drying late lactation cows off early, but be sure to monitor the performance of transition cows as a prolonged dry period can lead to other metabolic disorders**

Health: Impaired cow health is associated with elevated FFAs. Studies have indicated that cows with mastitis display elevated FFA levels in the milk (Needs and Anderson, 1984, Hanuš et al., 2016). An increase in somatic cell count (SCC) has been associated with elevated FFAs. As described above, cows in negative energy balance are likely to experience loss of body condition that can induce fat mobilization and elevated FFAs.

Considerations:

- **Consult your herd veterinarian about controlling subclinical mastitis and avoid milking higher SCC into the tank**
- **Ensure that cattle are meeting their energy requirements by monitoring body condition and avoid milking those with severe negative energy balance into the tank.**

Management: Insufficient milking system cleanliness through inadequate sanitization of pipelines, bulk tank, milking units and milk filters can increase FFA levels by promoting microbial bacterial growth and spontaneous lipolysis.

Considerations:

- **Ensure that ALL milking equipment is cleaned and sanitized immediately after each milking with a sufficient amount of hot water and chemicals that suit the water characteristics**
- **Inspect milk filters daily and change more regularly if required**

Cow's Diet: Fat supplements, such as palm fats, contain a high percentage of saturated fatty acids that may elevate certain FFAs (Wiking et al., 2019). An increase in fat substrate from these fat additives results in larger and unstable fat globules that are susceptible to increased lipolysis. Herds that utilize pasture as part of the cow's diet for at least some part of the year tend to have lower milk FFAs. Rations that are low in energy can induce negative energy balance in the cow and elevate serum non-esterified fatty acid (NEFA) levels that contribute to elevated FFAs. Rations that have lower crude protein are correlated with elevated milk FFAs as well (Hanuš et al., 2008). This is due to their effect of lowering milk protein and casein levels, which are negatively correlated with FFAs (Hanuš et al., 2008). Insufficient dietary zinc can lead to zinc deficiency which may increase FFAs (Hermansen et al., 1995).

Considerations:

- **Work with your nutritionist to feed a balanced ration that meets the energy demands of your herd**
- **Limit fat supplementation (if required) to less than 300g/head/day**
- **Allow milking cows to have pasture access at suitable times of year (if possible)**

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