Part 03 : Metabolic characteristics of lactating dairy cows

- The different metabolisms are closely linked. Some molecules resulting from one metabolism can thus constitute precursors for another metabolism: AA (nitrogen metabolism) can serve as a precursor for the synthesis of glucose (carbohydrate metabolism), and thus be used in energy metabolism. This explains why, during energy deficiency, the protein content of milk decreases.
- The chemical composition of milk is: ± 87% water, 5% lactose, ± 4% fat, just over 3% protein and ± 1% minerals.
- These constituents are almost all synthesized by the breast from precursor elements taken from the blood: glucose, acetic acid, ketone bodies, long-chain fatty acids and AA.

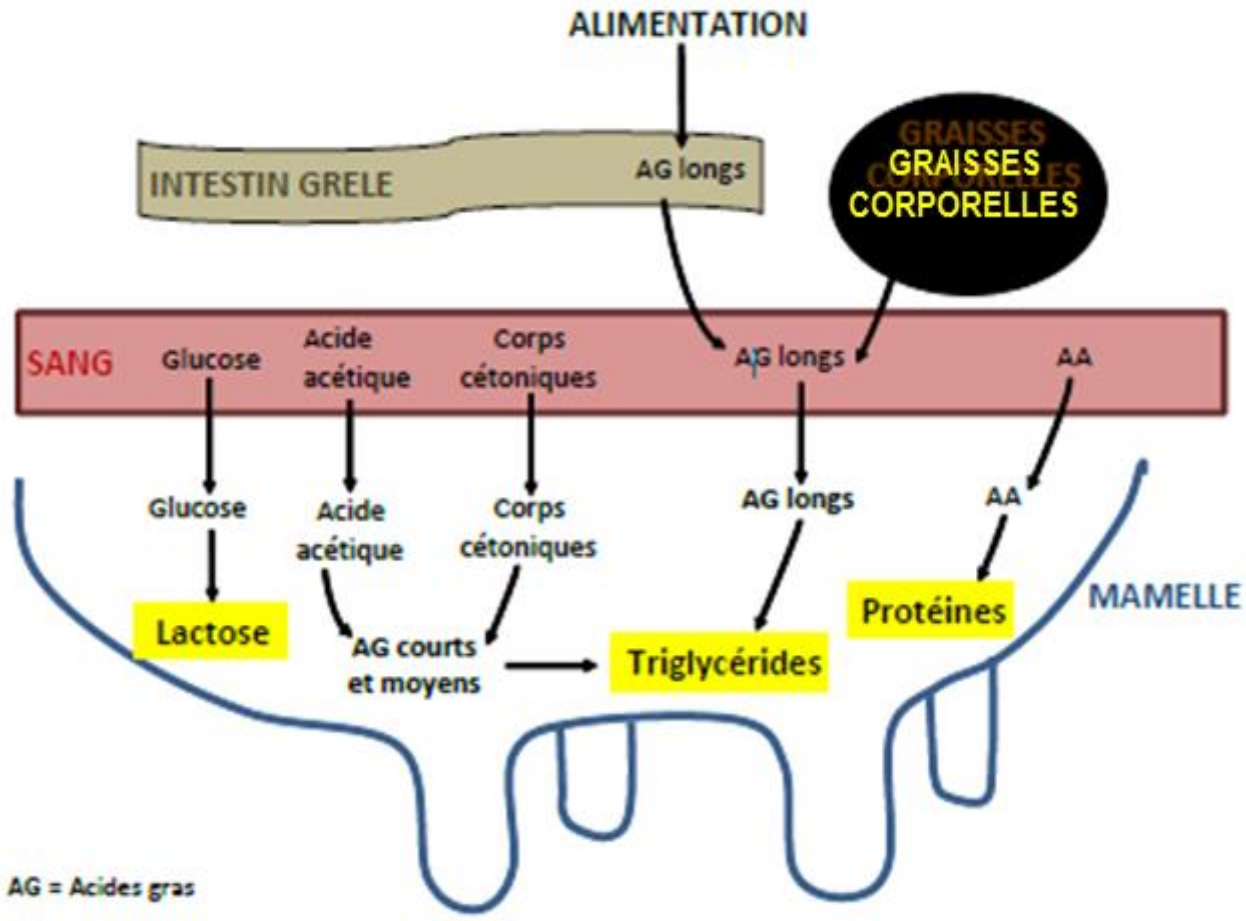
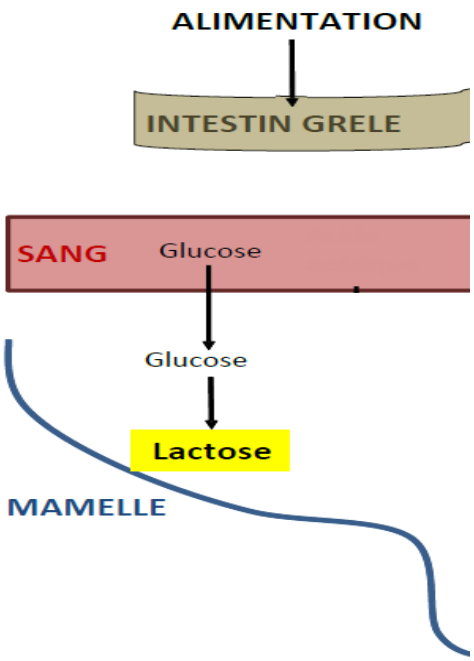


Diagram of the metabolisms enabling the synthesis of milk in the breast

1. Carbohydrate metabolism

- In ruminants, the glucose provided by the ration generally represents less than 5% of the energy absorbed, since it is transformed in the rumen into VFA.

- Therefore, the cow must synthesize glucose from other substances. This process is called "gluconeogenesis."
- The main precursors that will be used to synthesize this glucose are propionic acid and certain AAs.
- Propionic acid is produced by microbial digestion of carbohydrates. Its transformation provides 50 to 60% of the cow's glucose needs.
- Since it comes more from starch-related fermentation, it is possible that certain rations that are too low in energy or made up of forages (which favor the production of acetic acid to the detriment of propionic acid), such as hay, do not produce enough for lactating cows. In this case, gluconeogenesis is based on AA.
- In lactating cows, this use of AA can lead to a drop in milk protein levels.
- Glucose is of particular importance, as it contributes to the synthesis of lactose, the main carbohydrate constituent of milk: lactose results from the union of a glucose molecule and a galactose molecule, the latter itself being formed in the breast exclusively from glucose.
- The amount of milk a cow secretes depends on the amount of glucose made available to the mammary gland, with lactose levels varying little in milk. A dairy cow producing 30 L of milk must provide its mammary gland with almost 2 kg of glucose in addition to the 500 g needed to meet its maintenance needs.



2. Metabolism of AGVs

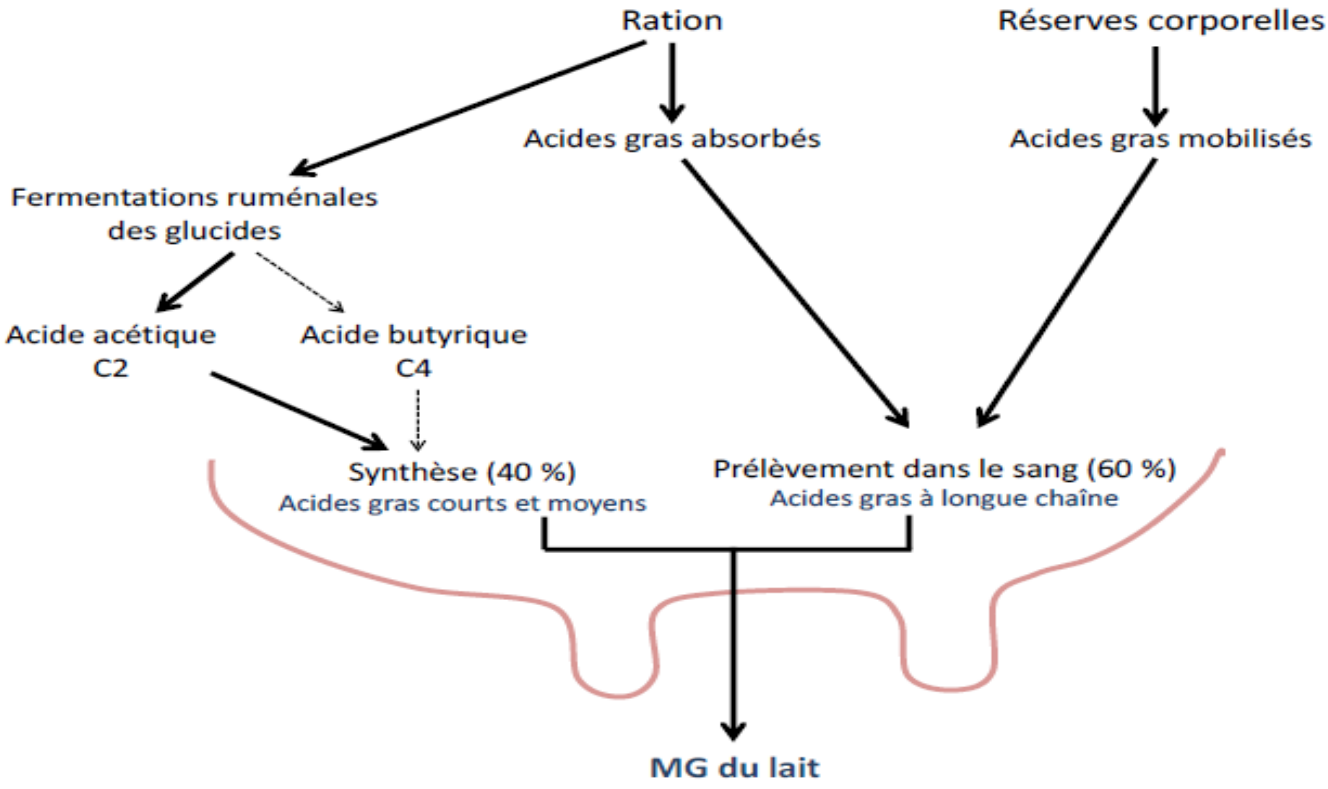
- VFAs (acetic acid, propionic acid and butyric acid) are produced by microbial digestion of carbohydrates.
    - *propionic acid*is mainly used for gluconeogenesis;
    - *acetic acid*, after processing, is used first of all to provide energy to the animal. In the udder, it serves as a precursor for the synthesis of short-chain and medium-chain fatty acids in milk;
    - *Butyric acid*is transformed almost entirely into ketone bodies (acetoacetate and β-hydroxybutyrate) during its absorption through the rumen wall. These ketone bodies are

used as energy suppliers, but also participate in the synthesis of short and medium chain fatty acids in milk at the level of the udder;

- These two VFAs cannot provide glucose by gluconeogenesis.

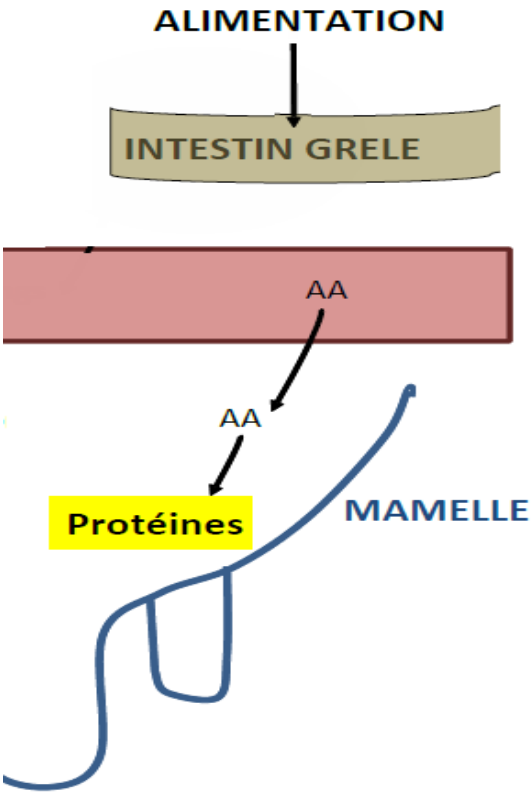
3. Lipid metabolism

- Triglycerides (1 glycerol + 3 fatty acids) make up the majority of the animal's fat reserves. They also make up the majority of milk lipids. The fatty acids they contain have two possible origins:
  - An extra-mammary origin (60% of milk fatty acids): the fatty acids are taken from the blood by the breast, and these are then long-chain fatty acids coming directly from food (food and microbial synthesis) or from the mobilization of body reserves
  - An intramammary origin (40% of milk fatty acids): the breast itself synthesizes fatty acids, from acetic acid and β-hydroxybutyrate, and these are then short and medium chain fatty acids.



- When the cow is deficient in energy, it draws on its body's reserves, and therefore its fat. This results in an additional influx of long-chain fatty acids into the blood, which are then taken up by the udder. This explains why when the cow's energy needs are not met, as is often the case in high-level dairy cows at the beginning of lactation, the milk fat content increases.
- At the level of milk fatty acids, there are:

- on the one hand, a relatively fixed component, consisting of short-chain and medium-chain fatty acids,
- on the other hand, a variable component, consisting of long fatty acids. It is possible to influence this latter fraction to a certain extent.



4. Protein metabolism

- In cattle, the AA present is used to synthesize proteins, which have a strict AA composition, genetically determined.
- A deficiency in an essential AA (methionine, lysine) can limit the production of protein in milk.
- AAs can also be used to synthesize glucose when needed. Therefore, there is competition for AA utilization between the protein synthesis pathway and the glucose synthesis pathway.
- This competition is one of the reasons that explains the low protein content of milk during energy deficit in cows: AA are preferentially used to synthesize glucose instead of being used to synthesize milk proteins.