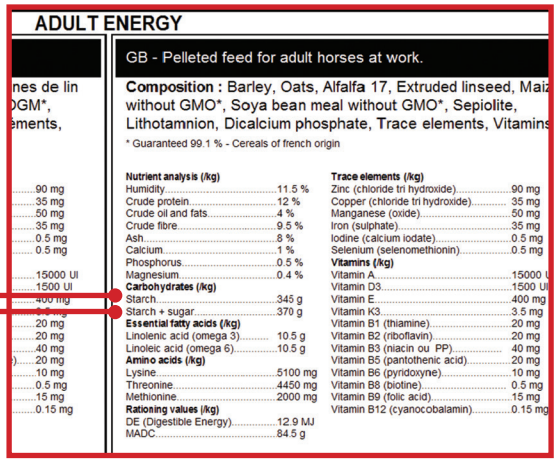
STARCH

STARCH
STARCH + SUGAR


ADULT ENERGY

GB - Pelleted feed for adult horses at work.

Composition : Barley, Oats, Alfalfa 17, Extruded linseed, Maiz without GMO*, Soya bean meal without GMO*, Sepiolite, Lithotamnion, Dicalcium phosphate, Trace elements, Vitamins

* Guaranteed 99.1 % - Cereals of french origin

Nutrient analysis (/kg)	
Humidity	11.5 %
Crude protein	12 %
Crude oil and fats	4 %
Crude fibre	9.5 %
Ash	8 %
Calcium	1 %
Phosphorus	0.5 %
Magnesium	0.4 %
Carbohydrates (/kg)	
Starch	345 g
Starch + sugar	370 g
Essential fatty acids (/kg)	
Linolenic acid (omega 3)	10.5 g
Linoleic acid (omega 6)	10.5 g
Amino acids (/kg)	
Lysine	5100 mg
Threonine	4450 mg
Methionine	2000 mg
Rationing values (/kg)	
DE (Digestible Energy)	12.9 MJ
MADC	84.5 g

Trace elements (/kg)	
Zinc (chloride tri hydroxide)	90 mg
Copper (chloride tri hydroxide)	35 mg
Manganese (oxide)	50 mg
Iron (sulphate)	35 mg
Iodine (calcium iodate)	0.5 mg
Selenium (selenomethionin)	0.5 mg
Vitamins (/kg)	
Vitamin A	15000 U
Vitamin D3	1500 UI
Vitamin E	400 mg
Vitamin K3	3.5 mg
Vitamin B1 (thiamine)	20 mg
Vitamin B2 (riboflavin)	20 mg
Vitamin B3 (niacin ou PP)	40 mg
Vitamin B5 (pantothenic acid)	20 mg
Vitamin B6 (pyridoxyne)	10 mg
Vitamin B8 (biotine)	0.5 mg
Vitamin B9 (folic acid)	15 mg
Vitamin B12 (cyanocobalamin)	0.15 mg

A molecule of reserve energy found in green plants, and stored in its organs of storage (seeds, roots, tubers, rhizomes and certain fruits) that allow the plant to survive during the dormant season. It is one of the principle calorie sources for the human species (cereals, etc.). **Furthermore, it is the primary energy source of the horse during effort and exertion.**

DEFINITION

A complex carbohydrate composed of many glucose molecules. It is the principal component of cereals.

% OF RAW INGREDIENT	STARCH	SIMPLE SUGARS
Oats	36.2	1.1
REVERDY Feeds	15 - 40	2.5 - 8
Berley	52.2	2.1
Maize	64.1	1.6

Table: The levels of starch and simple sugars found in cereals suitable for the horse. The levels found in the REVERDY range are given for comparison purposes only (Source: INRA, 2nd edition, 2004).

USE

Starch is a **versatile energy source** for the athletic horse. In the small intestine it is split into units of glucose which are then passed into the bloodstream. It can be used in different ways:

- Oxidised in order to directly produce energy.
- Stored in the form of muscle and hepatic glycogen or as lipids.

"Starch is the choice energy source for the synthesis of glycogen in so much as its' digestion leads to a rise in the glycaemia* and the insulinaemia*, two of the most important parameters implied in the synthesis of glycogen".
(Pagan et al. 1998)

*Glycaemia = The concentration of glucose in the blood (blood sugar level)
* Insulinaemia = The concentration of insulin in the blood

Muscle glycogen is an important fuel:

- **Energy production during effort** which favours performance.
- **Stored in the liver**: It will then be used to produce glucose which will be liberated into the bloodstream during work, this is essential, because glucose is the only fuel available to the central nervous system.

This regulation **helps prevent against the appearance of hypoglycaemia during exertion** which can be a potential cause of sudden tiredness.

THE IMPORTANCE OF THE QUANTITY OF STARCH FED PER MEAL

"It is recommended to give no more than 200 g of starch per 100 kg of live weight per feed" (Cuddeford 1999) that is to say 1 kg of starch per feed for a 500 kg horse, which corresponds on average to 2.8 kg (4 litres) of REVERDY feed per meal.

Above this level, the horse does not use his ration effectively, if an even greater overfeeding of starch occurs, that is to say a quantity exceeding 300 g per 100 kg live weight/meal (more than 5 L of REVERDY feed for a 500 kg horse) then the capability of the small intestine to digest and absorb the starch is exceeded.
In this case a non-negligible quantity of residual starch will pass directly into the large intestine and be at the origin of an acidification of the digestive contents (digestive acidosis) harmful to the gut flora (dysmicrobial).
The resulting consequences may be more or less serious, but can end in colic or laminitis.
However, for the most digestible forms of starch, it is possible to exceed 200 g of starch per 100 kg of live weight and per feed without disturbance to the digestion of starch in the small intestine.

The level of starch in a cereal or in a feed per crude kg has little value: it is the quantity of starch fed per meal and the digestibility of this starch which are of more importance.

FACTORS INFLUENCING STARCH DIGESTIBILITY

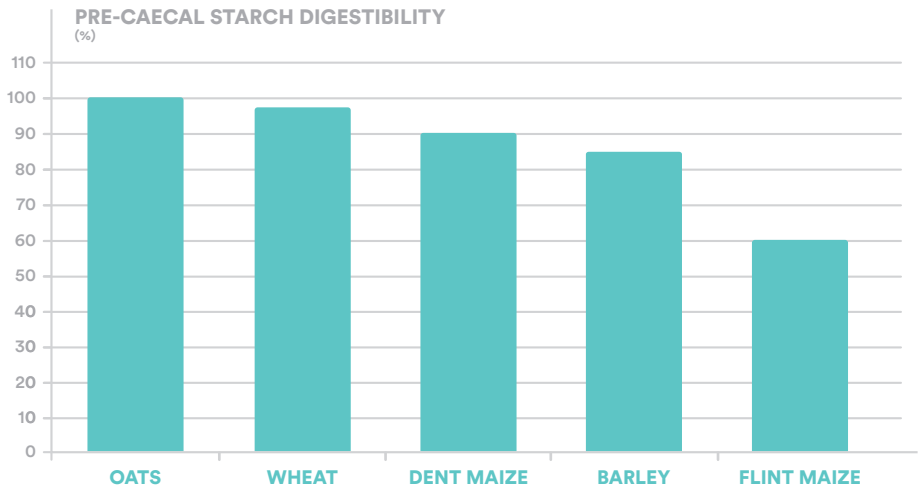
SOURCES OF STARCH

Even though all starches are constituted of glucose chains, **the way in which a molecule of starch is constructed varies greatly from one cereal to another** (the ratio amylose*/amylopectin*, nature of the endosperm* etc.). This difference in the architecture of different types of starch has an important impact upon the way in which it will be digested in the small intestine of the horse.

Amongst all the most commonly fed cereals to horses, **oats contain the most digestible form of starch followed closely by wheat, then comes barley and maize**. The digestibility of the starch contained in the latter depends on the variety of maize used (cf. the graph). Late varieties (dent maize) which are majoritarian in animal nutrition and used in our feeds, **contains a more digestible form of starch** than early varieties (flint maize). Furthermore, varieties containing a starch poor in amylose have greater digestibility. Thus, the **Waxy variety** of maize whose amylose content is close to 0% presents **superior digestibility to starch from dent maize varieties** which contain on average 25% amylose. Associated with flaking, Waxy maize provides very digestible starch.

PRE-CAECAL STARCH DIGESTIBILITY DEPENDING ON BOTANICAL TYPE

(Source: Jevardat de Fombelle et al., 2003)



***Amylopectin**: Branched chain of glucose molecules. It makes up 70 to 85% of starch. It is the most digestible form of starch which is responsible for the gelatinisation.
***Amylose**: Linear chain of glucose molecule taking a helical structure. It represents approximately 15 to 30% of starch composition knowing that the more amylose there is, the less the starch is digestible.
***Endosperm**: Plant tissue that is a nutritive reserve containing carbohydrates (starch) and proteins. Along with the embryo (germ) it makes up the centre of the seeds.

TECHNOLOGICAL TREATMENTS

We are able to distinguish many types:

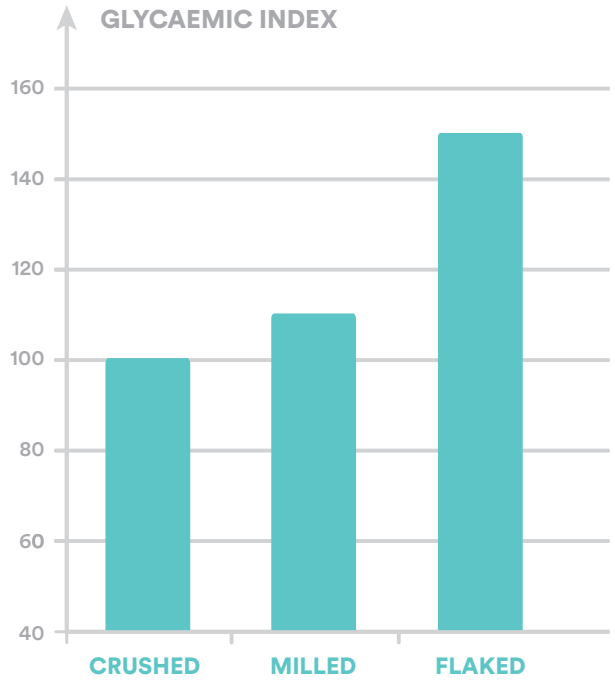
- **Mechanical**: grinding, rolling, crushing.
- **Thermic**, using dry heat: toasting, expansion, extrusion.
- **Thermo-mechanical** using a humid heat: Flaking and granulation (to a lesser extent).

Their objective is to increase starch digestibility in the treated cereals. They are above all of interest in cereals possessing less digestible starch (maize and barley). Oat and wheat starch being already very digestible, technological treatments have little effect on their pre-caecal* digestibility.

Flaking is commonly employed in horse nutrition, it corresponds to a flattening and a steam cooking which leads to hydration and a partial predigesting of the starch = gelatinisation. In the case of maize starch, **flaking significantly increases its digestibility and therefore its glycaemic index** (cf. graph), a parameter that we shall now examine.

GLYCAEMIC INDEX OF MAIZE DEPENDING ON TREATMENT PROCESS

(Source: Hoekstra et al., 1999)



***Pre-caecal**: The parts of the digestive tube situated before the caecum (large intestine) = the stomach and small intestine

GLYCAEMIC INDEX (GI)

DEFINITION

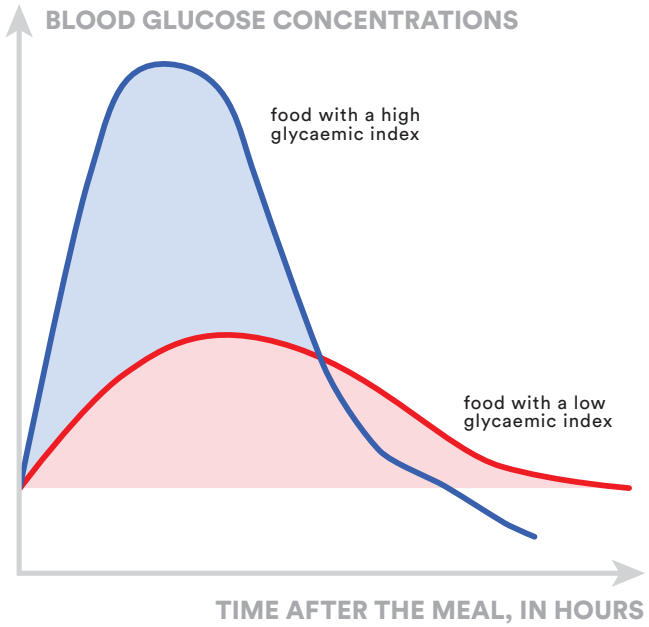
A System used to **classify food stuffs according to their effect on the glycaemia**.

Created by Canadian scientists at the beginning of the 1980's, it compares the exact quantity of carbohydrates available in each food, providing a numeric index based upon the glycaemia after a meal.
Initially development for human use, it has since been modified and recognised as being reliable for horses.

From a practical point of view, **it characterises the enzymatic digestibility of a carbohydrate source in the small intestine**:

- Feed sources that contain the most soluble carbohydrates, and that divide quickly during digestion have the highest glycaemic indexes.
- Those feed sources which contain the least soluble carbohydrates and who liberate very progressively glucose into the bloodstream (slowly digested) have the lowest glycaemic indexes.

EVOLUTION OF THE GLYCAEMIA AFTER A FEED DEPENDING ON THE GI OF FOOD



Whole maize grains, Ground maize, Flaked maize.

THE GLYCAEMIC RESPONSE AND THE HEALTH OF THE HORSE

The digestive system of the horse is adapted to having **many small meals throughout the day**; this corresponds to a life of grazing and browsing in a field. This type of diet leads to low glycaemic responses, even more so if the ingested foods have low glycaemic indexes (forage etc.).Furthermore, a very low glycaemic response is supposed to bring about a very low demand for insulin, so resulting in a **better long term stability of the glycaemia**. Thus the risks of fluctuations in the glycaemia and insulinaemia are diminished.

PATHOLOGICAL STATES RELATED TO/OR AGGRAVATED BY HIGH GLYCAEMIC INDEXES

A glycaemic response after a meal leads to the secretion of insulin in the blood, a hormone that drops the glycaemia by allowing glucose to enter the cells so that it can either be used or stored in the form of glycogen in the muscles and the liver. However, depending on the ampler of the glycaemic peaks, the frequency of their appearance and the sensitivity of the individual, disturbances in the healthy functioning of the organism can be observed in the more or less long term. The most frequent are resumed below:

● EXCESS FAT

The higher the glycaemic peak, the more insulin is secreted and greater is the quantity of glucose entering the cells. **In this case, part of the glucose cannot be stored in the form of glycogen. It will be transformed into fatty acids** which will then be stored in the adipose cells that constitute the fatty tissues situated at different places in the organism (under the skin, in the abdominal cavity, etc.). Therefore, the higher the glycaemic index of a carbohydrate, the more susceptible it is to promote an unwanted (in the majority of cases) excess of fat.

● BEHAVIOURAL PROBLEMS, EXCITABILITY

Insulin production brings an increase in the blood levels of a neurotransmitter that has an action on behaviour: the **serotonin**. Thus, the higher the glycaemic index of a carbohydrate, the greater will be the quantity of insulin and serotonin produced. It has been shown that a serotonin syndrome is manifested by mental and physical hyperactivity, a disorganisation of behaviour and mood change.
Consequently, the “excitable” properties of oats are not only due to avenin but can be equally explained by its highly digestible starch (this is equally valid for wheat and flaked cereals).

● CHRONIC MYOPATHIES (= “TYING- UP”)

Two types exist:

- **Recurring equine rhabdomyolysis (“RER”)**, the mechanism responsible for this condition is not fully known. However, it seems to be due to an **anomaly in the regulation of intra-cellular calcium** responsible for muscular contraction (while magnesium helps with muscle relaxation). These muscle cells present a dysfunction in carrying out the contraction – relaxation cycles. Also, during exercise (above all when long and slow) they may produce **excessive muscular contractions**, leading to the destruction of those affected muscle cells. This phenomena happens **mainly in nervous/excitable horses** (2/3 are female), it is logical that high glycaemic index carbohydrates are a predisposing factor (see below).
- **Polysaccharide storage myopathy (PPSM)** is seen less frequently (above all present in Quarter horses who are few in number in France). It is characterised by an excessive **accumulation of glycogen and an abnormal polysaccharide in muscular cells**

It affects calm horses in good condition. Consequently, it is important to restrict the entry of glucose into muscular cells. Therefore the use of highly digestible carbohydrates is not advisable.

***Serotonin syndrome**: Excess of serotonin in the central nervous system

ABOUT WHEAT...

Including wheat in the diet of horses is **not desirable** for numerous reasons:

- Firstly, as explained by R.WOLTER (1999) “wheat, more than any other cereal, risks forming doughy lumps in the digestive tract because of its’ richness in gluten” that is to say to **obstruct the digestive tract** (choke, oesophagus obstruction).
- Furthermore wheat grains contain an important quantity of **very fermentable starch** (common wheat starch = 60.5% crude starch INRA 2004), very degradable and so equally easily digested by the enzymes of the horse.

Consequently, its incorporation into equine feeds is likely to modify different points of the digestion and metabolism of carbohydrates:

- On one hand, it may result in **an increase in gastric fermentations (microbial)** these can be at the origin of painful distensions of the stomach through the large liberation of gases. Simultaneously the flora will produce an important quantity of lactic acid responsible for the appearance or **aggravation of stomach ulcers.**
- On the other, the high digestibility of wheat starch leads to a **large production of insulin** which can be a cause of harmful disruptions to the horse: **behavioural problems (excitement), muscle metabolism (tying-up) and osteoarticular problems (perturbed growth) etc...**

For these reasons we have chosen not to use this cereal.

● GASTRIC ULCERS

The higher the digestibility of the carbohydrate (high GI), the more susceptible it is to be fermented into organic acids (amongst them lactic acid) by the micro-organisms present in the stomach (see the diagram below). Thus lactic acid being aggressive for the gastric mucosa, its production favours the appearance of ulcers.

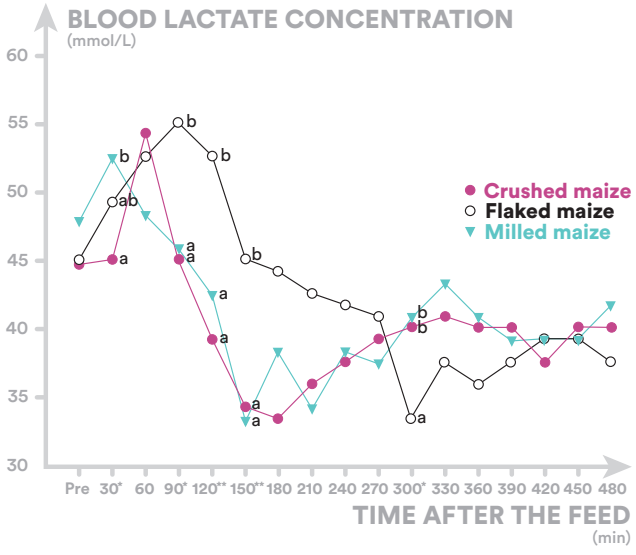
● OSTEOCHONDROSIS (OCD)

It has been demonstrated that mares producing foals suffering from OCD are statistically those who have, at the end of gestation, shown high insulin discharges after feeds. In fact it would seem that **hyperinsulinaemia disrupts the healthy development of cartilage cells by delaying their maturity**.

Consequently, feeding high GI indexed carbohydrates to broodmares at the end of pregnancy, or to foals seems to be a predisposing factor (see graph on the right).

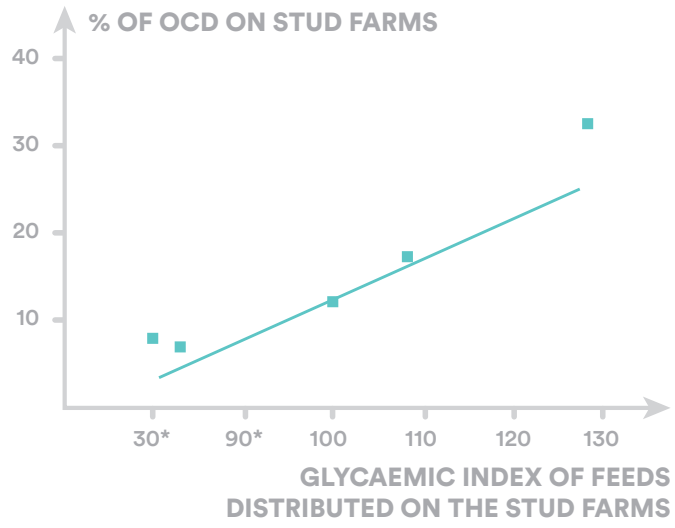
EVOLUTION OF THE BLOOD LACTATE CONCENTRATION AFTER THE FEED DEPENDING ON THE TECHNOLOGICAL TREATMENT UNDERGONE BY THE MAIZE

(Source: Hoekstra et al., 1999)



RELATION BETWEEN THE GLYCAEMIC INDEX OF FEEDS AND OSTEOCHONDROSIS

(Source: Pagan et al., 2001)



● PATHOLOGICAL STATES IN PRESENCE OF INSULIN RESISTANCE:

Horses suffering from **equine metabolic syndrome or from Cushing's' disease show hyperinsulinaemia associated with a prolonged hyperglycaemia after ameal**. The cells of the organism are less sensitive to insulin (insulin resistant), which restricts the entry of glucose into the cells, thus hyperglycaemia. On the other hand, cells in the organism that do not need insulin to absorb blood glucose, such as the cells constituting the micro-capillaries that assure good vascularisation of the hoof, this translates by an increase of the glucose concentration inside them. Now, the excess glucose being toxic for them, it leads to their death or vascularisation defects in the feet characterized by **laminitis**.

Therefore, it is logical to avoid feeding carbohydrates with a high GI, which will aggravate the hyperinsulinaemia and the hyperglycaemia, and hence the health of horses showing insulin-resistance.

TO SUM UP

In brief, it is preferable **to distribute a diet composed essentially from forage** because the low glycaemic index carries a lower risk of disrupting the regulation of the glycaemia and thus the health of the horse.

However, **in the athletic horse**, energy requirements being up to twice those of a horse at rest and knowing that the synthesis of glycogen is favoured by the appearance of sufficient glycaemic and insulin responses, **resorting to cereals that have a higher glycaemic index seems inevitable**.
But which ones should be chosen?

... AND FLAKED CEREALS

Flaking is a thermo mechanical procedure in a humid environment which significantly increases the digestibility and therefore the glycaemic index of cereals.Consequently, and even if it is **"the dose that poisons", we advise against the use of flaked cereals for breeding**, in particular in the broodmare at the end of gestation and for the foal under the mother.**We equally advise against their use in horses that suffer from the aforementioned pathological states**: excess fat, behavioural problems, chronic myopathies, gastric ulcers, Cushing's disease, equine metabolic syndrome and laminitis.

Flaked **cereals do have their interest for specific uses**. Indeed it is recommended to use them (in moderation) if we wish to:

- Facilitate the digestion of starch because of:
  - **Insufficient enzymatic secretions** in the senior horse.
  - Feeding **very high levels of cereals** in the **working horse**.
- Reconstitute glycogen reserves:
  - **After muscular effort**: this is notably the role of a mash fed to race horses after an intense effort.
  - **During prolonged effort**: the ingestion of flaked cereals **maintains a normal glycaemia during endurance competitions**. This practice is comparable to a cyclist eating cereal bars during a race.
- Improve body condition = **Preparation for the sale ring.**

The adjective digestible is a synonym of fermentable in the case of starch.

WHICH TYPE OF STARCH TO CHOOSE?

Simplistically we could think that the more a starch is digestible the better it is for the horse. But it is more complicated. Firstly, **in the case of starch the adjective "digestible" is a synonym of "fermentable"**. Indeed, a carbohydrate digested in the small intestine is fermentable by the micro-organisms of the stomach. Furthermore, **"digestible", rhymes with a high glycaemic index**. As we have previously explained, a ration presenting a high GI is susceptible of disrupting the health of the horse.

In brief, each compartment of the digestive tube relates to a problem related to carbohydrates:

● STOMACH

It contains a large population of bacteria capable of fermenting carbohydrates into organic acids, including lactic acid, aggressive for the gastric mucosa.
The use of a **slow releasing, little fermenting carbohydrate** is thus the most wise = maize and barley.

● SMALL INTESTINE

Carbohydrates broken into glucose molecules will cause a glycaemic response having more or less beneficial repercussions on the functioning of the whole organism. The objective is to obtain sufficient absorption of glucose whilst avoiding large fluctuations of the glycaemia. It is thus **pertinent to associate slow releasing starch (barley, maize) with fast releasing starch (oats, flaked maize, etc.)**. The proportions of slow and fast releasing starch will depend on the breed, the age and the activity of the horse. For example, for the horse in work, the greater the energy requirements, the more the proportion of digestible starch must be increased in the ration.

● LARGE INTESTINE

Resistant starch, non-digested in the pre-caecal part will arrive in the caecum and be fermented into organic acids by lactic acid producing bacteria, with the possible resulting consequence of a drop in the PH of the digestive contents which is able to strongly perturb the beneficial cellulytic flora (which digests fibres).
Thus **the use of digestible carbohydrates (oats flakes etc.,) greatly limits the risks of digestive acidosis**.
However, if the quantities of starch fed per meal do not exceed 200 g for 100 kg of live weight per meal, the distribution of slower releasing starch (barley, maize) will not cause problems.

TO SUM UP

Distributing reasonable amounts of slow releasing starch (barley, maize) associated with a bigger or smaller proportion of digestible starch (oats, flaked maize, etc.) seems to be the best compromise for the horse in good health whose energy requirements are not able to be totally met by forage alone.

This is the strategy we have chosen to adopt in REVERDY feeds.
Indeed, this method of rationing allows a limitation of gastric fermentations which can lead to the appearance of ulcers and disturb the metabolism of carbohydrates with all the possible consequences on the health of the horse.
However, other parameters have an influence on the ferment ability/digestibility of a given starch: notably the moment at which forage is distributed, the size of the feed, the level of fibre, fats and oils in the ration.
This is what we will address.