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Guide to Feed Preservation

Solutions for Agricultural Operations

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We create chemistry

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We create chemistry

Contents

1 Introduction

In times of low sales revenues from animal products, farm-produced feed becomes particularly important, as does its quality.

Unpredictable weather patterns and heavy rainfall combined with a more and more effective harvest chain constantly present new challenges to the harvest of feed such as hay or grain.

BASF provides solutions that help optimize the nutrient content and quality of harvested feed and improve the hygiene of by-products and farm-produced compound feed.

This is where the known mold-inhibiting effects of the propionic acid Luprosil® are particularly useful. Depending on the application, the product Amasil® NA, containing formic acid, is also recommended. Formic acid is very effective in specifically preventing the growth of bacteria such as *E. coli* or salmonella.

We also feature a number of additional products whose ratio of formic acid to propionic acid has been adapted to suit a wide variety of application areas. The products Lupro-Grain® and Luprosil® NC contain buffered propionic acid. Lupro-Cid® NA and Lupro-Mix® NA contain additional amounts of formic acid as well.

Lupro-Grain® and the 'NC' and 'NA' products are highly effective and significantly more user-friendly than pure acids, since they are less corrosive to infrastructure and are not considered hazardous materials under transport regulations.

Our "Guide to Feed Preservation – Solutions for Agricultural Operations" is a manual that will help farmers master the challenges of harvesting and storing feed.

2 Importance of feed hygiene

Feedstuffs such as grain, grain maize, pulse crops or even compound feed have a naturally high population of bacteria, mold fungi and yeasts. Up to 6 million bacteria, 40,000 fungal micro-organisms and 50,000 yeasts are tolerated as an upper limit per gram of grain! The micro-organisms have an ideal substrate and under certain conditions can multiply very quickly. If a high water content coincides with the naturally high microbe population, explosive propagation of the fungi, yeasts and bacteria occurs. In turn the metabolism of these micro-organisms increases the moisture content and the temperature of the feed, which can accelerate the spoilage process.

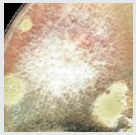
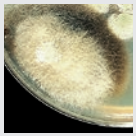
In the case of oats this critical moisture boundary lies at about 14%. Other types of grain can be kept stable under summer temperature conditions only at a grain moisture content of under 15%. Pulse crops such as peas and field beans, as well as rapeseed, spoil at moisture contents in excess of 12% water.

We recommend preservation with Luprosil® for a grain moisture content of 14% or more for all grain types and for a moisture content of 12% or more for pulse crops.

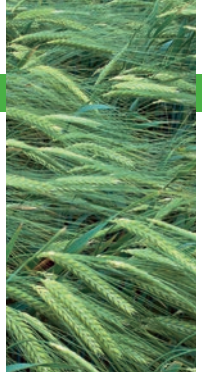
However, acid treatment to reduce the microbe population and to improve the hygiene quality is worthwhile even at lower moisture contents and is particularly recommended when feeding breeding sows and piglets, as well as for use in liquid feed. Feed spoilage, which ranges from a musty odor to visible mold, and possibly toxin formation, is the consequence of microbe multiplication.

Once toxins have formed from fungi or bacteria, they are almost impossible to eliminate. Spoiled feed can thus lead to reduced livestock performance. Advanced spoilage of feed can result in serious illnesses of the animals, occasionally with fatal consequences. Residues of certain mycotoxins such as ochratoxin and aflatoxin in the final products—sausage, meat and milk—can also occur.

Important toxins of mold fungi, their toxicity and desease symptoms for livestock

	Type of mold fungus	Formed toxin	LD 50	Disease symptoms
	***Aspergillus flavus***	Aflatoxin B1	0.36 mg/kg duck, orally 5.5 mg/kg rat, orally	Liver necrosis, diarrhoea, carcinoma
		Aflatoxin G1	0.78 mg/kg duck, orally	Vascular wall ruptures with bleeding
		Aspergillic acid	150 mg/kg mouse, ip.	Dizziness, vomiting, death
	***Aspergillus ochraceus***	Ochratoxin A	0.5 mg/kg duck, orally	Kidney damage, increased urinary excretion
	***Penicillium expansum*** ***Penicillium urticae***	Patulin	10 mg/kg mouse, sc.	Decreasing blood pressure, increasing heart rate, neurotoxic
	***Fusarium tricinctum***	T-2 Toxin	4 mg/kg rat, orally	Oedema, decrease of white corpuscles
	***F. graminearum*** ***Gibberella zeae***	F-2 (Zearalenon)	0.75 mg/kg mouse, ip.	Vulvovaginitis in pigs, disturbance of fertility
	**Fusarien**	DON (Vomitoxin)	70 mg/kg mouse, ip.	Vomiting, enteritis in pigs

3 Advantages of preservation



3.1 Natural occurrence of propionic acid

The main active ingredient of the BASF-preservation agent is propionic acid, which occurs as an organic acid in nature. Propionic acid is a building block in the metabolism of animals and plants. For instance, up to 1.5 litre propionic acid are formed daily by the rumen microbes of dairy cows and this represents an important source of energy for the ruminant.

Natural propionic acid also occurs in silage. It is found in food too. Swiss cheese contains up to 1 per cent propionic acid which is formed during the ripening of the cheese. This concentration is sufficient to preserve grain with a moisture content of 26% for a whole year.

3.2 Inhibitory effect on fungi, yeasts and bacteria

Propionic acid shows broad, antimicrobial activity against fungi, yeasts and bacteria, which lasts up to one year at sufficient doses. The number of fungi, yeasts and bacteria is reduced drastically by preservation. Subsequent further multiplication of the microbes is successfully suppressed by Luprosil®. These two effects, microbe reduction and prevention of microbe multiplication, are well illustrated, for example, in a preservation test with winter wheat.

Luprosil®'s ability to preserve grain is very little affected by the grain moisture content. However, the required Luprosil® dose increases in line with increasing grain moisture content and longer storage periods. For instance high-moisture maize, even with a water content between 40 and 50%, can be protected against spoilage for a whole year with Luprosil®.

In addition to preservation in storage, it is particularly important in practical farming that acid treatment allows the production of low-microbe and hygienically safe feed grain, which relieves the burden on the immune system of the animals and has a stabilising effect on the digestive operations. This promotes feed intake and digestibility.

Untreated barley after 4 weeks of storage (25% moisture content)

Barley treated with Luprosil® after 4 weeks of storage (25% moisture content)

Preservation test with winter wheat: Microbe development on wheat (17% moisture content) preserved with 0.65% Luprosil® directly after harvest (microbes per gram)

Storage time, months*	Fungi	Yeasts	Bacteria
0	27,000	5,000	36 million
1	< 15	< 15	670,000
6	0	0	6,100
12	0	0	500

* Months after preservation
MATTHIAS 1998, Haus Düsse

Field fungi and store fungi are virtually completely killed off by Luprosil® at the time of harvesting and reproduction of mold fungi during storage is suppressed. This successfully prevents the formation of mycotoxins from the time of harvesting onwards. However, mycotoxins which are formed up to the time of harvesting by field fungi (e. g. the fusariotoxins zearalenone and DON = Desoxynivalenol), cannot be eliminated by acid treatment, and remain in the grain. Thanks to acid preservation, however, it is possible to harvest the grain already at the optimum ripening time, despite a relatively high grain moisture content. This eliminates the waiting period for complete drying of the grain, which under adverse weather conditions may take days or even weeks. Thus, the time frame for the growth of field fungi and the possible formation of mycotoxins can be effectively shortened by an early harvest and preservation with acid.

3.3 Effects on insect pests

Grain weevil infestation in stored grain is a recurrent problem. The damage caused by this known grain pest can be considerable. In practice it has been demonstrated that after a Luprosil®-addition of 1% about 50–60%, and after an addition of 2% about 90–95% of the grain weevils die off. An addition of 1% Luprosil® upwards impedes the egg laying of the grain weevil. Doses between 0.5 and 1% Luprosil® have a preventive effect against damage by insects and normally no infestation with grain weevils or mites is apparent during storage.

Grain weevil

3.4 Impacts on the grain

The acid treatment minimizes breathing losses during storage, since the propionic acid acts on the metabolism of the grain. In line with the increase in the Luprosil® dose, enzyme systems in the corn are blocked, the corn breathing declines and the germinability is lost. That is why storage losses due to grain breathing hardly occur at doses of approx. 0.70% propionic acid and more.

Seed grain and brewer's grain should not be treated with Luprosil® products since the germinability of the grains is impaired. Furthermore, conservation by acid is not permitted for breadstuffs and grain for distilling purposes.

3.5 Advantages of moist grain preservation in the sectors of labour organisation and investment costs

The preservation procedure can easily be integrated into the organisation and the circumstances of the individual farm. This results in the following advantages:

1. Very high work rate during harvesting since the performance of the dosing equipment can easily be adjusted to the farm situation.
2. Low capital tie-up due to low procurement costs for dosing and screw conveyor in comparison to drying facilities. The equipment can also be used on an inter-farm basis.
3. Existing buildings can be used as stores (barn, storage halls and silage silos etc.).
4. Independence of external drying facilities and rising heating oil costs.
5. Less dependence on the weather and hence more flexibility for machine use during harvesting, since grain with a moisture content above 14% can be harvested.
6. The inhibition of grain respiration minimizes the loss of dry matter and carbohydrates.

4 Products for preservation

4.1 Which product for which application?

For which preservation problem do you need a solution? The following table is intended to help you to select the right preservation agent easily. The left column of the table shows the most important applications for our Luprosil®-brands, and in the right part the products and their suitable fields are tabulated. These recommendations include not only the preservation performance, but also the application properties of the products. For instance, Luprosil® is in principle very well suited for protecting a Total-Mix-Ration (TMR) against post-heating, but we recommend Luprosil® NC and Lupro-Grain® for this, since they do not have a caustic effect and have only a low corrosive action.

Choose the right product for your application! On the next few pages you will learn more about the composition and the user properties of our acid products.

4.2 Ingredients and product descriptions

For decades now, propionic and formic acid have been used widely in feed preservation as liquid acids under the brand names Luprosil® and Amasil®. Both products are very effective but, as caustic acids, require a high material standard and carefully implemented occupational safety measures during use.

Which product for which application?

Preservation	Luprosil®	Lupro-Grain®	Luprosil® NC	Lupro-Mix® NA	Lupro-Cid® NA	Amasil® NA
Moist grain whole corn	++	++	+	–	–	–
Moist grain meal / coarsely ground	++	++	(+)	–	–	–
Pulse crops	++	++	–	–	–	–
On-farm compound feed	++	++	++	++	++	+
Liquid feed	+	+	–	++	++	+
Total-Mix-Ration (TMR)	+	++	++	++	(+)	–
By-products	++	+	(+)	++	++	++

++ = very well suited + = well suited (+) = conditionally suited – = not suited

Ingredients and pH values of the Luprosil® and Amasil® brands

	Luprosil®	Lupro-Grain®	Luprosil® NC	Lupro-Mix® NA	Lupro-Cid® NA	Amasil® NA
State	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
pH	2.3*	4.2	6.8	3.4	2.7	2.5*
Density g/l (20 °C)	990–998	1031	1070	1207	1256	1301
Corrosiveness	+++	+	+	++	++	++
Propionic acid (%)	99.5	90–92	53.5	38	18	–
Formic acid (%)				34	54	75
Ammonia (%)		4	9.5			
Propandiol (%)		4	11.5			
Natrium (%)				8	8	7
Water (%)	0.5	Max 2	25.5	20	20	18

+++ = very corrosive ++ = corrosive + = slightly corrosive
* 100 g/litre of water

For this reason, we have only recommended Luprosil® propionic acid (99.5%) for use in agricultural applications but not the much more hazardous formic acid. Luprosil® propionic acid is caustic and has a corrosive effect on metals such as e. g. boiler plate and non-alloyed steel. Despite this, the product is indispensable for preservation at high moisture contents.

As an alternative to the use of caustic acids, user-friendly NC products (noncorrosive products) were developed specifically for farmers. Through a buffering step, the biological effect is attenuated from caustic to not caustic (irritating). The pH of the acid products was moderately increased so that burns to the skin do not occur (However, all products remain dangerous to the eyes! Protective goggles must be worn!). Furthermore, the erosion of materials susceptible to corrosion, such as boiler plate, is significantly reduced compared to pure acids. Hence, the NC products are very easy to use, gentle on materials and not a hazardous material as defined by the transport regulations, thus allowing the product to be transported without limitations on quantity.

A period of continuous development and constant product improvement has now yielded the two NC products Lupro-Grain® and Amasil® NA. These products are very similar to the pure acids Luprosil® and Amasil® 85 with respect to their active ingredient concentrations. Of these two products, Lupro-Grain® represents the buffered propionic acid (since 1998) and Amasil® NA the buffered formic acid. Specifically developed for agricultural use, a buffered alternative to caustic formic acid is now also available!

As is the case for Lupro-Grain®, Luprosil® NC is based on buffered propionic acid. The almost completely neutralised ammonium propionate (pH 6.8) is particularly recommended for TMR (Total-Mix-Ration) stabilisation. To effectively combine the strengths of formic and propionic acid in one application, the acid blends Lupro-Mix® NA and Lupro-Cid® NA were developed. The combination of propionic acid and formic acid in these products is very effective against fungi, bacteria and yeasts. Besides featuring an optimal combination of propionic and formic acid, these buffered products likewise are easy to handle and less corrosive. As is the case for Lupro-Grain®, Luprosil® NC and Amasil® NA, they belong to the NC product family, are classified as being only “irritating” and are not a hazardous material as defined by the transport regulations.

However, these advantages for the user of the NC products must be set against the somewhat high demands made of dosing and the necessary precision of distribution. Lupro-Grain® and Luprosil® NC are more viscous than Luprosil®. Before use, therefore, the capacity of the dosing unit for these products must be gauged in litres (see also the chapter on Techniques of Grain Preservation). Furthermore, Lupro-Grain® and Luprosil® NC become more viscous when they are cooled (e. g. during cool nights). Despite the same flow rate display on the dosing unit, the acid quantity dosed then drops and there may be insufficient dosing. As rule of thumb, if the temperature of the Lupro-Grain® and Luprosil® NC during grain preservation is 5 °C higher or lower than it was during gauging of the dosing equipment, then the equipment is to be gauged again in this temperature range.

This applies equally to the formic acid-containing products, Lupro-Mix® NA, Lupro-Cid® NA and Amasil® NA as well.

As a strong, organic acid, Luprosil® has a caustic effect on the skin. The products Lupro-Grain®, Luprosil® NC, Lupro-Mix® NA, Lupro-Cid® NA and Amasil® NA are not caustic, but instead are classified in the far less dangerous class 'irritating'. Despite this, handling of all acid products calls for appropriate protective equipment (including tightly closed safety goggles) during processing.

Please study Chapter 12 (p. 66–69) on the topics Occupational Safety and First Aid Measures carefully.

4.3 Energy contents of the Luprosil® products

Luprosil® is an energy-rich substance and 1 kg propionic acid contains the energetic feed value of about 2 kg barley. The acid products described are all absorbed without residues in the stomach and intestine and are available to the animal organism for energy use.

The high energy value of propionic acid is used for example to prevent ketosis in dairy cows when propionates are included in the feed. The following table provides an overview of the energy contents of the products.

Energy contents of Luprosil® and Amasil® compared to barley

Animal species	Luprosil®	Lupro-Grain®	Luprosil® NC	Lupro-Mix® NA	Lupro-Cid® NA	Amasil® NA	Barley
Dairy cow (MJ NEL/kg)	14.6	14.1	9.7	7.1	5.2	3.6	7.2
Pig (MJ ME/kg)	20.7	20.0	13.8	9.8	6.8	4.2	12.4
Poultry (MJ AME/kg)	20.7	20.0	13.8	9.8	6.8	4.2	11.2
Fattening cattle (MJ ME/kg)	18.2	17.6	12.1	8.9	6.5	4.5	11.3

5 Technique of grain preservation

5.1 Technique of Luprosil® application for moist grain preservation

When acid is used for preservation purposes the grain is mixed in a screw conveyor with a liquid acid product. The dosing depends on the grain moisture content and the intended duration of storage.

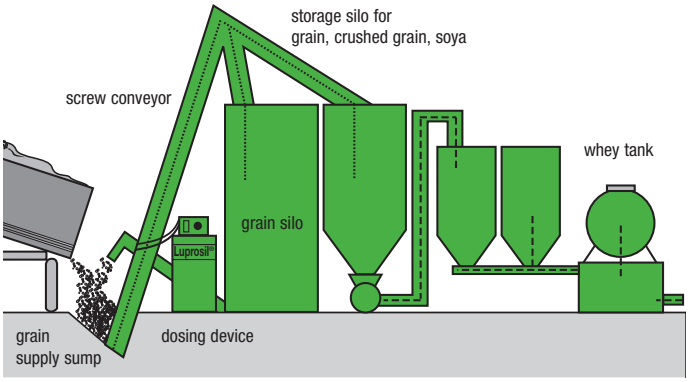
The objective of the process is to moisten all corn grains with the preserving acid if possible. The Luprosil® products are always applied undiluted for grain preservation!

The acid products are sprayed via nozzles into a screw conveyor with special dosing equipment for acids.

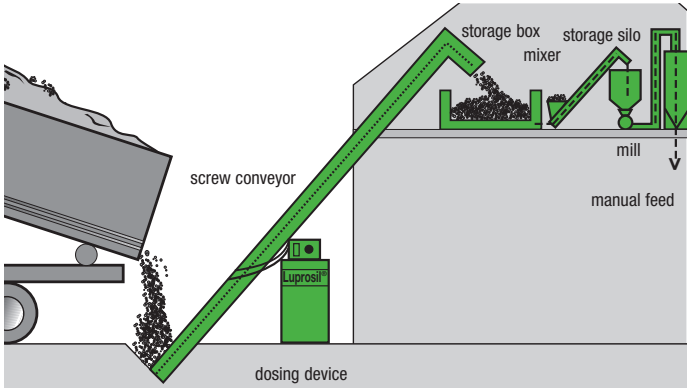
It is not possible to inject Luprosil® directly into the grain conveyor blower, since this leads to high acid losses in the waste air. The consequence is insufficient dosing and endangering of persons in the vicinity of the grain outlet!

The following technical characteristics apply for the screw conveyor:

- minimum length 3 m
- nozzles to be mounted at a spacing of 1.5 screw conveyor windings
- number of nozzles depends on the screw conveyor diameter:
  < 180 mm diameter: 2–3 nozzles
  180–200 mm diameter: 3–4 nozzles
  > 200 mm diameter: min. 4 nozzles
  (In the case of buffered acid products use the higher number of nozzles.)
- screw conveyor setting angle at least 30 degrees for good mixing (mixing elements should be installed in the case of trough screw conveyors).
- operate the screw conveyor at 2/3 the maximum rate for loose mixing of the grain



Application of Luprosil® to grain



Application of Luprosil® to grain

For safe preservation the following quantities must be determined as precisely as possible:

- **The moisture content of the grain**
  Measurement is absolutely necessary!
- **The grain conveying rate of the screw conveyor**
  To measure this the time taken to convey a known quantity of grain must be ascertained (measure the time, weigh the quantity and extrapolate to one hour = tonnes/hour). It should be noted that moist grain flows through the screw conveyor more slowly than dry grain, which is why the conveyor rate can best be determined with the grain to be preserved. In order to ensure good mixing, the screw conveyor should not be operated at a speed in excess of 2/3 the maximum conveyor rate.
- **The flow rate of the acid product at the dosing equipment**
  Although most dosing devices are equipped with a flow meter (display in litre/hour), it is vital to check the equipment performance before each season. If Luprosil® is used for preservation, the capacity of the entire apparatus including the nozzles should be gauged with water in litres and the flow rate display in litres per hour is to be checked.

For the buffered product, Lupro-Grain®, (and for Luprosil® NC) the capacity of the dosing equipment must be gauged in a separate operation. This is because the buffered acid products have a higher viscosity than Luprosil® or water. Moreover the viscosity of the buffered acid products also depends on the temperature. NC products such as Lupro-Grain® and Luprosil® NC become more viscous when they, for example, cool down overnight!

In both cases, therefore, when changing from Luprosil® to a buffered acid product or if the buffered acid product cools overnight, the quantity of acid conveyed is reduced. Although the flow meter on the dosing apparatus still shows the same flow rate, less acid product is being sprayed into the grain. This results in underdosage and the success of the preservation operation can thus not be guaranteed.

It is therefore necessary:

- to gauge the capacity of the dosing apparatus, including the nozzles, by litres directly with the buffered acid product,
- to measure the temperature of the buffered acid product before use, and in the event of temperature increase, and especially of temperature decrease, to gauge the capacity of the dosing apparatus again. As a guide, if the acid temperature changes by 5 °C by comparison with the temperature on the day the capacity was gauged, the flow rate of the dosing equipment must be gauged again under the new temperature conditions.

Example for a dosing device for Luprosil®

Gauging vessel for buffered acid products (e. g. Lupro-Grain®)

After these preparatory measures have been completed, the necessary application rate can be determined and set, on the basis of the grain moisture content and the desired storage period.

Sample calculation:

1. The measurement of the grain moisture content shows 18%. The desired storage period is 12 months. In the dosing table for Luprosil® the value of 0.65% is read off for 18% moisture content and 12 months storage duration. This corresponds to 6.5 litre per tonne grain.
2. The screw conveyor conveys 1,500 kg barley in 5 minutes. This results in a conveyor rate of 18 tonnes per hour.
3. The dosing unit now has to convey 6.5 litres of Luprosil® x 18 tonne grain = 117 litres in one hour. A conveyor rate of 120 litres/hour (117 litres rounded up) is set at the dosing unit. In order to make sure that no untreated grain reaches the store, it is important to switch on the dosing pump first, and then the screw conveyor.

Dosing allowances and further tips for grain preservation:

- **Conveying preserved grain by blower:**
  If grain preserved with acid is to be conveyed further by a grain blower directly after acid treatment, intermediate storage of one hour is necessary. If direct connection of the blower after the dosing equipment cannot be avoided, the product application rate recommended in the table must be increased by at least 10%.

- **High storage intake temperatures of the grain:**
  At grain storage intake temperatures of over 35 °C, an allowance of 10% extra on the dosing rate is recommended, since at these temperatures some of the acid can evaporate.

- **High incidence of pests:**
  If there was a high incidence of pests in the previous year and in the event of high grain storage temperatures and dumping height, the grain is often in danger of pest infestation (granary weevil, rice-flour beetle, saw-toothed grain beetle, etc.) and mites. In this case, it is recommended that the dosage be increased to 0.7–1.0% Luprosil® or Lupro-Grain® regardless of the moisture content of the grain. This dosage does not guarantee protection against pest infestation, however in practice it has shown a good repellent effect. This is in addition to cleaning and disinfecting the granary, and not a substitute for it.

- **When should preservation be carried out?**
  Treatment should be carried out directly after the harvest, since the moist grains warm up very quickly due to microbial activity. Although subsequent treatment of stored grain products is possible and can stop the development of micro-organisms and the increase in temperature, the application of the preservation agent is difficult. This is because the grains tend to form lumps as the temperature rises, so uniform wetting with the acid becomes progressively more difficult. Note, too, that subsequent acid treatment cannot eliminate any losses already sustained and any toxins already formed (e. g. mycotoxins).

- **Care of dosing equipment and screw conveyor:**
  After carrying out the preservation procedure, thoroughly clean the screw conveyor several times using untreated grain or with seasoned acid grain, bran or sawdust. After use, wash the equipment with water. Also rinse through the dosing equipment with water.

- **Is it expedient to cover the grain with film sheeting?**
  Do not cover preserved grain with film sheeting! If you do so, condensation can form under the film sheeting. This wets the top layer of grain which can spoil as a result.

- **Can moist and dry parcels of grain be stored together?**
  Treated moist grain should not be stored together with dry, untreated grain, since the moisture will travel into the dry grain, spoiling it. The two batches must therefore be separated by film sheeting, or the entire lot should be treated with the same dose of Luprosil®.

- **Aeration of preserved grain?**
  The aeration of grain preserved with Luprosil® or with Lupro-Grain® is generally not recommended. This procedure depletes the grain of propionic acid, which is carried away by the waste air and may lead to odour nuisance or condensation at the silo roof. Aeration must only be carried out as an emergency measure for countering the warming of the grain. The cause of the microbial warming must be identified and corrective measures may be required (e. g., underdosing or insufficient distribution of the preservative is to be corrected by subsequent treatment with Luprosil®).

Acid-resistant coating on concrete

No coating

5.2 Storage of preserved moist grain

Grain preserved in accordance with the recommendations does not form lumps and remains free-flowing. That is why it can be piled as high as dry grain.

The following storage methods are very suitable:

- free heaps in halls, barns, old buildings (in the case of a concrete floor place a layer of film sheeting on the floor or apply an acid-resistant coating to the floor)
- wooden boxes below the roof, and tower silos in wood
- tower silos with acid-resistant inside coating (glass, enamel, plastic)
- concrete silos (with acid-resistant coating)

Luprosil® is a liquid with a corrosive action. That is why feeds preserved with Luprosil® cannot always be stored in unprotected containers or silos made of sheet iron, galvanised metal or other materials susceptible to corrosion. First, these materials are more or less strongly attacked depending on the Luprosil®-content of the goods in storage. Second, the moist grain located close to the walls can spoil, since the propionic acid forms compounds with the nonresistant material and the preserving action is restricted in these marginal areas.

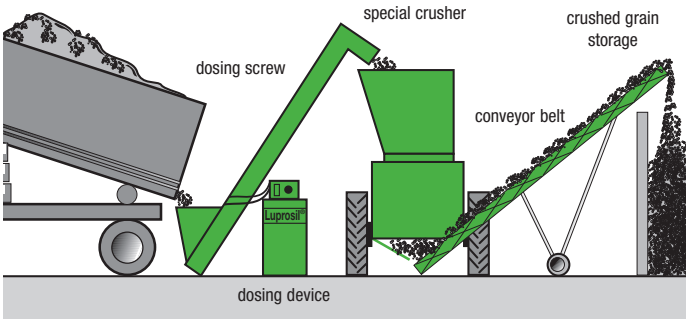
The buffered acid products Lupro-Grain® and Luprosil® NC are much less corrosive than Luprosil® or pure propionic acid. Despite this, even with these products it is not advisable to store moist grain directly after treatment in silos made of galvanised sheet or iron sheet. The grain freshly treated with acid can attack the zinc coating and lead to pitting. Non-acid-resistant storage containers can be used for storing moist grain under the following conditions. However BASF accepts no liability for increased wear due to the use of acid:

- In the case of grain moisture content up to and including 18% (corresponding to an application rate of 0.65% propionic acid) it is sufficient to leave the grain in intermediate storage for a few hours after the acid treatment so that the propionic acid can be absorbed into the grains. This measure reduces a large part of the corrosive action.
- If intermediate storage of the grain is not possible, or if grain is preserved at a moisture content of over 18%, we recommend an acid-proof coating or lining of the silo with acid-proof plastic sheeting.

5.3 Processing preserved moist grain

Moist grain with a water content of up to max. 20% can be crushed easily with commercially available standard hammer mills. At higher moisture contents, only hammer mills with a blower can be used. As the moisture content increases the selection of the right screen size (up to 20% moisture content = 4 mm; above 20% = 6 mm) is crucial.

Crushing is possible without any problem at high moisture contents. Moist grain with high moisture contents can only be processed in feed mixers when mixed with dry components. In practice it has been shown that mixtures with a total moisture content of below 20% can be processed without any problem.



Dosing crushed grain with Luprosil®

5.4 Preservation of crushed grain with acid products

In this process the grain is crushed immediately after harvesting, preserved with acids and then stored for a period of up to 12 months. To achieve good distribution the acid products have to be added to the grain before or in the mill (Dosing table see p. 34). These acid doses result in complete preservation.

The crushed grain can be heaped up loosely. It should not be compacted. If it is stored under cover it does not need to be covered by plastic sheeting. Concreted areas with a protective coating or lined with film sheeting and clamp silos are suitable for storage. In the case of clamp silos film sheeting as protection against rain should be placed over the grain as late as possible to give the crushed grain time to cool down.

The ensiling of crushed grain differs substantially from the complete preservation of crushed grain described above. For ensiling the usual measures to produce good silage should be taken. The ground material should be compacted and it must be covered with airtight plastic sheeting. The dosing tips set out on page 65 for preventing post-fermentation and postwarming in the ensiled crushed grain only apply under these conditions.

6 Dose recommendations for preservation

6.1 Preservation of harvested crops (grain, corn, pulse crops)

Moist grain (whole grain)

Application rates for Luprosil® (in %) for moist grain (whole grain), all grain types including corn

Moisture content %	Preservation period, months			
	1	1–3	3–6	6–12
Up to 16	0.35	0.45	0.50	0.55
16–18	0.40	0.50	0.55	0.65
18–20	0.45	0.55	0.65	0.75
20–22	0.50	0.65	0.75	0.85
22–24	0.55	0.70	0.85	0.95
24–26	0.60	0.80	0.95	1.05
26–28	0.70	0.90	1.05	1.15
28–30	0.80	1.00	1.15	1.30
30–32	0.90	1.10	1.25	1.45
32–34	1.00	1.20	1.35	1.60
34–36	1.10	1.30	1.50	1.75
36–38	1.25	1.45	1.65	1.90
38–40	1.40	1.60	1.80	2.05
40–42	1.55	1.75	1.95	2.20
42–44	1.70	1.90	2.10	2.35
44–46	1.85	2.05	2.25	2.55
46–48	2.00	2.20	2.40	2.75
48–50	2.15	2.35	2.60	2.95

Allowances: see page 26

Luprosil®, Lupro-Grain® and Luprosil® NC are used to preserve feed grain, corn and pulse crops used for feeding. Seed grain and brewer's grain should not be treated with Luprosil® since the germinability of the grains is impaired. Furthermore, acid conservation is not permitted for grain for bakeries and grain for distilling purposes.

Application rates for Luprosil® NC (in %) for moist grain (whole grain)

Moisture content %	Preservation period, months			
	1	1–3	3–6	6–12
Up to 16	0.70	0.90	1.00	1.10
16–18	0.80	1.00	1.10	1.30
18–20	0.90	1.10	1.30	1.40
20–22	1.00			

Note: at moisture contents above 20% the use of Luprosil® or Lupro-Grain® (until 40% moisture contents) is recommended. Allowances and sample calculation on page 26–27!

Application rates for Lupro-Grain® (in %) for moist grain (whole grain)

Moisture content %	Preservation period, months			
	1	1–3	3–6	6–12
Up to 16	0.40	0.50	0.60	0.65
16–18	0.50	0.60	0.65	0.80
18–20	0.55	0.65	0.75	0.90
20–22	0.60	0.80	0.90	1.00
22–24	0.75	0.95	1.05	1.15
24–26	0.90	1.10	1.20	1.30
26–28	1.05	1.25	1.35	1.45
28–30	1.20	1.40	1.50	1.60
30–32	1.35	1.55	1.65	1.75
32–34	1.50	1.70	1.80	1.90
34–36	1.65	1.85	1.95	2.10
36–38	1.80	2.00	2.10	2.25
38–40	1.95	2.15	2.25	2.40

Note: at moisture contents above 40% the use of Luprosil® is recommended. Allowances and sample calculation on page 26–27!

Moist grain (meal and crushed)

Application rates for Luprosil® (in %) for crushed grain/meal			
Moisture content %	**Preservation period, months**		
	1	**1–3**	**6–12**
Up to 16	0.40	0.50	0.70
16–18	0.50	0.60	0.85
18–20	0.60	0.70	1.00
20–22	0.70	0.80	1.15
22–24	0.80	0.90	1.25
24–26	1.00	1.10	1.25
26–28	1.15	1.25	1.50
28–30	1.30	1.40	1.65
30–32	1.45	1.55	1.80
32–34	1.60	1.70	1.95
34–36	1.75	1.95	2.10
36–38	1.90	2.10	2.25
38–40	2.10	2.25	2.30

Note: after the meal is taken into storage the surface should be treated with 1 litre Luprosil® per square metre.

Application rates for Lupro-Grain® (in %) for crushed grain/meal			
Moisture content %	**Preservation period, months**		
	1	**1–3**	**6–12**
Up to 16	0.45	0.60	0.80
16–18	0.50	0.70	0.95
18–20	0.60	0.85	1.10
20–22	0.70	1.00	1.25
22–24	0.85	1.15	1.40
24–26	1.05	1.30	1.55
26–28	1.20	1.45	1.70

Note: after the meal is taken into storage the surface should be treated with 1 litre Lupro-Grain® per square metre.

Pulse crops and rapeseed

Luprosil® can also be used to preserve field beans, peas, soybeans, lentils and rapeseed. The Luprosil® application technique is identical with that for moist grain (see Chapter 5.1).

Application rates for Luprosil® (in %) for pulse crops or rapeseed				
Moisture content %	**Preservation period, months**			
	1	**1–3**	**3–6**	**6–12**
Up to 12	0.35	0.45	0.50	0.55
12–14	0.40	0.50	0.55	0.65
14–16	0.45	0.55	0.65	0.75
16–18	0.50	0.65	0.75	0.85
18–20	0.55	0.70	0.85	0.95
20–22	0.60	0.80	0.95	1.05
22–24	0.70	0.90	1.05	1.15
24–26	0.80	1.00	1.15	1.30
26–28	0.90	1.10	1.25	1.45
28–30	1.00	1.20	1.35	1.60

Note: Allowances and sample calculation on page 26–27!

Application rates for Lupro-Grain® (in %) for pulse crops or rapeseed				
Moisture content %	**Preservation period, months**			
	1	**1–3**	**3–6**	**6–12**
Up to 12	0.40	0.50	0.60	0.65
12–14	0.50	0.60	0.65	0.80
14–16	0.55	0.65	0.75	0.90
16–18	0.60	0.80	0.90	1.00
18–20	0.65	0.85	1.00	1.15

Note: at moisture contents above 20% the use of Luprosil® is recommended. Allowances and sample calculation on page 26–27!

6.2 Preserving farm-produced compound feed

Farm-produced compound feed frequently has a high population of fungi, bacteria and yeasts. This is frequently due to the grain being too moist when stored, or condensation forms in the feed or grain silo and leads to re-wetting and hence spoilage. Furthermore, the temperature of the compound feed is often increased by the milling and mixing operation to a level which is ideal for the development of micro-organisms. In the case of excessive microbe populations, especially of fungi, the following problems can occur:

- the free-flowing capacity of the feed drops, lumps form and clog the conveyor equipment,
- in the case of intensive reproduction of the micro-organisms, the feed warms up and under certain circumstances mycotoxins can be formed by storage fungi,
- the animals may develop digestive disorders; the feed intake drops, the feed conversion rate and weight gains decline.

This can be remedied by preservation with Luprosil® or Lupro-Grain®. The Luprosil® product is added to the other compound feed components (e. g. grain, soybean meal) in the mixer right at the start of the mixing operation to ensure good distribution. The Luprosil® already used in the moist grain preservation can be taken into account proportionally.

Application rates (in %) of Luprosil® or Lupro-Grain® for the preservation of compound feed (stability 6–8 weeks)

Moisture content of the grain/the complete feed in %	Application rate Luprosil® in %	Application rate Lupro-Grain® in %
Up to 14	0.30	0.35
14–16	0.40	0.45
16–18	0.50	0.55

In line with the dosing instructions, Luprosil® can be replaced without any problem by the low-corrosive Lupro-Grain®. Furthermore, mixtures of Luprosil® and soya oil (to upgrade the energy content of the feed) are hardly corrosive at all. Recommended mixing ratios which remain stable are: 10% Luprosil® to 90% oil or 20% Luprosil® to 80% oil.

6.3 Stabilizing liquid feed

Feed residues in the transport lines, rinsing water tank and mixing vat offer yeasts and bacteria optimal facilities for rapid multiplication in liquid feed at the usually high animal housing temperatures. This leads to fermentation processes with gas formation in the feeding plant and results in bloating, diarrhoea or even sudden deaths in the case of fattening pigs.

The addition of Lupro-Mix® NA or Luprosil® reduces the number of yeasts, bacteria and fungi in the liquid feed, prevents their reproduction, and thus stops such undesirable fermentation processes. Application is possible by adding acids continuously to the liquid feed, or by flushing the piping weekly with an acid-water mixture.

Permanent additive to the liquid feed:
As a permanent additive a dose of 0.15–0.25 litre Lupro-Mix® NA per 100 litres liquid feed is recommended.

Special, acid-resistant dosing equipment is available for the application. It allows the acids to be added to fresh water or in the mixing vat. The advantage of mixing directly in fresh water is that the flushing water is thus also treated with acid. This water often carries a yeast load and thus leads to repeated new inoculation of the fresh feed mix with harmful microorganisms.

Weekly cleaning

The feeding system is cleaned once a week with a two per cent solution of Lupro-Mix® NA in water (2 litres Lupro-Mix® NA/100 litres liquid feed).

The volume of flushing water should be equivalent to 10% of the mixing capacity and be left to act on the piping until the next feeding operation. This flushing solution can be added to the new feed mix without any problems.

Alternatively Luprosil® can be used instead of Lupro-Mix® NA as a permanent additive (0.15–0.25%) or for weekly flushing (2%).

It is advisable to preserve feed components such as CCM, grain or crushed grain with Luprosil® or Luprosil® products directly after harvesting (pages 32, 33 and 35). Luprosil® or Lupro-Mix® NA can also be added to the liquid feed via the preservation of by-products such as whey, brewer's yeast or food residues. The dose for the by-product here is approx. 1% Lupro-Mix® NA or Luprosil®; an acid concentration of 0.15–0.25% should be achieved in the liquid feed. The reduced microbe population of the acid-treated by-products has a favorable effect on the hygiene status of the liquid feed.

6.4 Acidification of drinking water

Hygiene plays an important role not only in the feed, but also in the liquid intake. In drinking water the pH value limits the growth of micro-organisms and algae. It should be between 4.5 and 4.9.

With the addition of 0.1–0.25% Lupro-Mix® NA, the pH of the water can be shifted to this range which is hostile to microbes. If problematic conditions exist (e.g. mucus formation on the drinking nipples), the dosage should be increased to 0.3%.

The microbes load is reduced substantially by this acid mixture and growth of algae in the drinking facilities is prevented. We recommend acid-resistant medicament dosing devices for the application. The pH value achieved in the drinking water must be checked in order to set the dose.

6.5 Stabilizing roughage

Stabilizing TMR/preserving cattle feed in the mixer-feeder-wagon

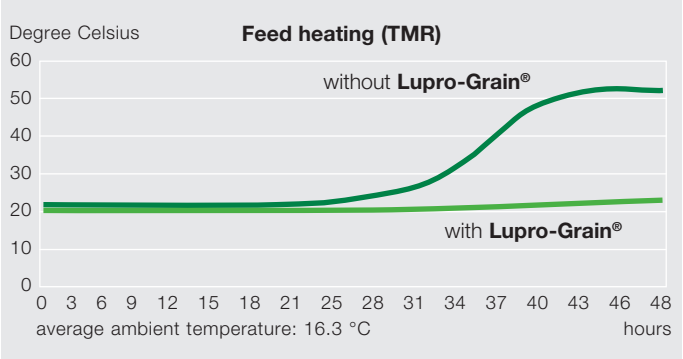
The importance of the Total-Mix-Ration (TMR) in feeding high-performance dairy cows has increased in recent years. For this kind of feeding the total dairy cattle ration comprising silage, hay, various feed concentrates and mineral feed are mixed together in the mixer-feeder-wagon. Here silage is loosened up considerably and comes into contact with atmospheric oxygen. The consequence is often heating of the entire TMR within a few hours, especially during the summer months. Nutrient losses and a decline in feed intake are the consequence.

This post-heating can be successfully prevented with Lupro-Mix® NA, Lupro-Grain®, Luprosil® NC or Luprosil®, whereby the first two products named are more suitable for administration in the mixer-feeder wagon due to their harmlessness and lower corrosiveness. Our recommended doses for adding in the mixer-feeder wagon are:

Lupro-Grain® 0.35% (3.5 l/t mixed ration)
Luprosil® NC 0.6% (6 l/t mixed ration)
Luprosil® 0.3% (3 l/t mixed ration)
Lupro-Mix® NA 0.35% (3.5 l/t mixed ration)

At this dosage approx. 100–150 g propionate is taken in per cow and day (only 40–60 g propionate if Lupro-Mix® NA is used), which can have a preventive effect on the development of ketosis disorders.

The increase of temperature in TMR with and without acid treatment was determined over various periods in an experiment. The following figure shows the temperature curves within 48 hours, illustrating the stabilising effect of Lupro-Grain® on TMR.



Preserving hay

Compared to well-dried ground hay, which can only be stored at residual moisture contents of 10 to 15%, Lupro-Grain® protects hay of up to 25% moisture content safely from mold and other harmful micro-organisms. Heating of the hay, nutrient loss and formation of dust are prevented.

Application rates of Lupro-Grain® for the preservation of hay in round and block big bales

Moisture content (%)	Lupro-Grain® (l/t)
Up to 20	5-6
21–25	8

Note: let hay rest before storage, so that residual moisture can dissipate.

Effect of the preservation of hay (92% dry matter after ageing) with Lupro-Grain® (6 l/t) on the microbial counts after 3 months of storage (block big bales, ground drying)

Hay	Control	Lupro-Grain®
Bacteria (micro-organisms/g)	35,000,000	602,000
Fungi (micro-organisms/g)	6,491,000	21,000
Quality level	II–III	I

I: High quality without restriction,
II: Slightly increased microbial count, quality diminished
III: Increased microbial count, low quality

6.6 Preservation of by-products

By-products from breweries

- **Brewer's yeast (liquid)**
  Feeding fresh, untreated brewer's yeast to pigs can cause difficulties, since the yeast cells can cause undesired fermentation in the digestive tract of the animals, which leads to sustained diarrhoea.

  That is why up to now it has been recommended that fresh brewer's yeast be boiled first. However, this involves substantial costs and is also connected with a decline in the digestibility of the nutrients. With the acid products Luprosil®, Lupro-Cid® NA, Amasil® NA or Lupro-Mix® NA, the yeast cells can be killed off safely without nutrient losses.

  Recommended dose: 1 litre per 100 litre brewer's yeast for the safe killing of yeast cells within a short period of time.

- **Brewer's grains**
  Especially during the summer months brewer's grains spoil within a few days because they offer ideal conditions for yeasts and fungi. With Luprosil® brewer's grains can be protected against spoiling. For surface treatment (approx. 30 cm layer thickness) 1 litre Luprosil® and 4 litre water per square metre must be mixed and then poured onto the surface. Then seal off the brewer's grains (air-tight) with plastic sheeting at once. Additional mechanical working in is advisable. Do not store for more than three weeks after commencement of unloading. The same effect can also be achieved with 1 litre of Lupro-Mix® NA mixed with 4 litres of water. Application is the same as for Luprosil®.

Brewer's yeast (liquid)

Brewer's grains

By-products from dairies

- **Whey and skim milk**
  The recommended doses for Lupro-Mix® NA or Luprosil® are: 1% for preservation lasting several weeks 0.3%: the start of microbial spoiling can be delayed by approx. 2 days. Using the same dose, Lupro-Cid® NA and Amasil® NA are also recommended for this application.

Preservation of stale bread and biscuit wastes

- **Stale bread**
  For storage beyond the specified sell-by date, 0.5 litre Luprosil® per 100 kg stale bread should be used. Mill the bread wastes and mix well with Luprosil®.

- **Biscuit wastes**
  The recommended dose is 0.3 litre Luprosil®/100 kg biscuit wastes for storage beyond the specified stability date. Crush the biscuit wastes and mix well with Luprosil®.

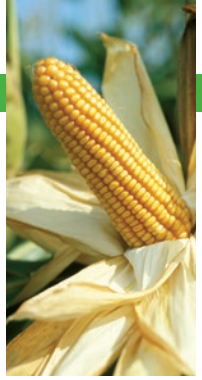
6.7 Preservation and acidification of feed mixes for pigs and poultry with Lupro-Mix® NA, Lupro-Cid® NA and Amasil® NA

For feed preservation and to achieve hygienically safe feed as well as to lower the buffer capacity and the pH value of the feed, Lupro-Mix® NA, Lupro-Cid® NA and Amasil® NA are recommended. The acidifying effect of the preservatives increases with rising formic acid levels in the following order: Lupro-Mix® NA, Lupro-Cid® NA and Amasil® NA. However, due to its propionic acid content, Lupro-Mix® NA is most effective against moulds followed by Lupro-Cid® NA. The desired effect, that is, more acidification or more mould inhibition in the compound feed, determines the choice of the preservative.

The following doses are recommended for farm-produced compound feeds:

Animal species	Live weight	Lupro-Mix® NA, Lupro-Cid® NA or Amasil® NA kg/t complete feed
Piglet	6–20 kg	8–10
Fattening pig	20–50 kg	6–8
Fattening pig	50–100 kg	5–6
Breeding sows		6–8
Broiler		3–5
Turkeys		5–6

7 Cost comparison



For farm-processed grains, acid preservation and storage as moist grains provide an interesting alternative to grain drying.

The many advantages acid treatment has over drying concern mainly feed hygiene but also economical aspects. The following tables compare preservation costs with Luprosil® and Lupro-Grain® to costs for grain drying.

The calculation examples show that acid preservation is usually preferable to drying because of its significantly lower fixed costs.

The difference in the variable costs reduces with rising energy prices in favor of acid preservation. Even more significant is the higher moisture content of the freshly harvested crops, frequently observed in corn maize. The energy requirements for drying, rise more than proportionately with the residual moisture in the grain and thus increase the preservation costs drastically.

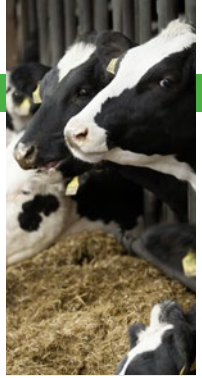
7 Cost comparison

Processing 100 t farm-produced feed cereals per year (20% residual moisture content, drying to 14% or acid preservation of moist cereals, storage time 12 months)									
Preservation method		**Batch drying**		**Continuous flow drying**		**Luprosil®**		**Lupro-Grain®**	
System size		1 t/h		1 t/h		10 t/h		10 t/h	
Fixed costs total*			14.88 €/t		25.87 €/t		6.34 €/t		6.34 €/t
Variable costs	Heating oil (0.55 €/l)	7.50 l/t	4.13 €/t	7.50 l/t	4.13 €/t				
	Electricity (0.14 €/kWh)	6.50 kWh/t	0.91 €/t	6.50 kWh/t	0.91 €/t	1.50 kWh/t	0.21 €/t	1.50 kWh/t	0.21 €/t
	Luprosil® (1.20 €/kg)					10.00 l/t	10.20 €/t		
	Lupro-Grain® (1.25 €/kg)							10.00 l/t	12.50 €/t
	Labor (12.50 €/man hour)	0.20 man hour/t	2.50 €/t	0.20 man hour/t	2.50 €/t	0.10 man hour/t	1.25 €/t	0.10 man hour/t	1.25 €/t
	total		**7.54 €/t**		**7.54 €/t**		**11.66 €/t**		**13.96 €/t**
Total costs			**22.42 €/t**		**33.41 €/t**		**18.00 €/t**		**20.30 €/t**

Processing 400 t farm-produced feed cereals per year (20% residual moisture content, drying to 14% or acid preservation of moist cereals, storage time 12 months)									
Preservation method		**Batch drying**		**Continuous flow drying**		**Luprosil®**		**Lupro-Grain®**	
System size		2 t/h		2 t/h		10 t/h		10 t/h	
Fixed costs total*			6.70 €/t		8.59 €/t		1.59 €/t		1.59 €/t
Variable costs	Heating oil (0.55 €/l)	7.50 l/t	4.13 €/t	7.50 l/t	4.13 €/t				
	Electricity (0.14 €/kWh)	6.50 kWh/t	0.91 €/t	6.50 kWh/t	0.91 €/t	1.50 kWh/t	0.21 €/t	1.50 kWh/t	0.21 €/t
	Luprosil® (1.20 €/kg)					8.50 l/t	10.20 €/t		
	Lupro-Grain® (1.25 €/kg)							10.00 l/t	12.50 €/t
	Labor (12.50 €/man hour)	0.20 man hour/t	2.50 €/t	0.20 man hour/t	2.50 €/t	0.10 man hour/t	1.25 €/t	0.10 man hour/t	1.25 €/t
	total		**7.54 €/t**		**7.54 €/t**		**11.66 €/t**		**13.96 €/t**
Total costs			**14.24 €/t**		**16.13 €/t**		**13.25 €/t**		**15.55 €/t**

* Fixed costs
Drying: Annual depreciation 8.3%, interest 4%, repairs 2%, insurance fees 1%,
Acid preservation: Annual depreciation 12.5%, interest 4%, repairs 2%, insurance fees 1%,
both related to the purchase costs.

8 Use of organic acids as silage additives



In central Europe the dairy farm has to provide high quality roughage for the winter period on about 200 days of the year. Many farms have switched to all-year silage feeding. However, profitable milk production depends essentially on a high milk performance from the roughage. That is why the demands made today on the energy content, the fermentation quality and the storage stability of silages are very high. Weather conditions have a critical influence on the success of silage making. During damp weather conditions the green matter may often not be sufficiently pre-wilted; this can result in faulty fermentation with the formation of butyric acid.

A careful ensiling technique is important, so that the silage not only achieves a high feed value, but also retains this during the long storage period. Conditions are also particularly difficult if silage has to be offered during the warm periods of the year, such as during all-year indoor feeding of dairy cattle or pig fattening with Corn-Cob-Mix. Post-heating of the silages frequently occurs, which leads to nutrient losses or even toxin formation.

In both problem cases, i. e. with insufficiently wilted silage and with silages jeopardised by post-heating Lupro-Mix® NA and Luprosil® can help. With these silage additives based on the organic acids propionic and formic acid, very good silage qualities can be produced and secured even under difficult ensiling conditions.

Factors for successful ensiling

Fermentability of the feed

Feed type

Easy fermentation
- Silage maize, beet leaves, rutabaga and turnips

Normal fermentation
- Meadow and pasture grass, amount of grass clover, lupine, rapeseed and mustard

Difficult fermentation
- Lucerne, red clover, green rye

Fertilization
- Nutrient contents
- Composition of the flora in the grassland

Harvesting time
- Water content
- Nutrient content

Better feed quality garantees better silage quality

Factors for successful ensiling

Ensiling technique

Silage design
- Number
- Size
- Shape
- Material

Mechanization
- Pre-wilting
- Crushing
- Impact force
- Compaction
- Air seal

Additives
- Organic acids and salts
- Butyric acid bacteria

Better ensiling conditions reduce losses

8 Use of organic acids as silage additives

8.1 What are difficult ensiling conditions?

Difficult ensiling conditions can be equated with poor environmental conditions for the lactic acid bacteria. There is a lack of readily available plant sugars and the lactic acid fermentation starts slowly. Fermentation bacteria such as clostridia can multiply and form undesirable fermentation products, e.g. butyric acid. Difficult ensiling conditions are already associated with the composition of the forage plants. Due to a high protein content in relation to the sugar content, the forage species lucerne, clover, peas and green rye are considered to be difficult to ensile.

A further factor making silage production difficult is insufficient pre-wilting, such as can happen if the weather situation is unfavorable. Silage with dry matter contents of below 30% is difficult to ensile, since the plant sugar content is not yet concentrated enough for swift and efficient lactic acid fermentation.

By using Lupro-Mix® NA, an ensiling additive with propionic and formic acid, it is possible to produce a good silage even under the difficult ensiling conditions described. This is demonstrated in the following test (see table).

Ensiling test with Lupro-Mix® NA: meadow grass with 24.2% dry matter, 90 days ensiling period

Parameter	Control (untreated)	Lupro-Mix® NA (4 l/t)
Dry matter loss (%)	9.2	5.0
Aerobic stability (days)	8.0	7.8
pH-value	4.2	4.0
Lactic acid (g/kg)	51	44
Acetic acid (g/kg)	17	16
Butric acid (g/kg)	12	0
NH_3-N (%)	8.3	5.8
DLG score	53	100

Kalzendorf, 2010

Without acid treatment the silage is spoiled or of low value, but with Lupro-Mix® NA a good silage quality is produced from the same raw materials.

As is generally known, 85% formic acid is also used as an ensiling additive for wet silages, that is, for difficult ensiling conditions. By using formic acid to rapidly decrease the pH, the fermentation bacteria in the silage are inhibited. Amasil® NA, a buffered acid product, can completely replace the caustic formic acid in this application.

8.2 What can be done against post-heating of silages?

Energy-rich silages such as maize silage, CCM or grass silage with a high residual sugar content often tend to warm up after unloading from the silo. With the introduction of air a strong multiplication of yeasts and fungi takes place, which leads to high nutrient losses and may even go as far as complete spoiling. Highly pre-wilted grass silages with a DM content of over 40% can also be affected by post-heating due to the high residual sugar content, and tend to become unstable after unloading has taken place.

Suitable measures for improving aerobic stability are, swift filling of the silos, a high rate of compaction and careful, air-tight covering with silo sheeting. In addition the advance during unloading should be 1 m/week in winter and 2 m/week in summer. These measures can be supplemented by the use of the silage additives Lupro-Mix® NA or Luprosil®. The fact that these products provide protection against post-heating losses is confirmed by the DLG Quality Symbols for improvement of aerobic stability. The table below shows the results of an ensiling test which demonstrates the improved stability and lower losses after treatment with Lupro-Mix® NA compared with the untreated control silage. In addition the fermentation pests are repressed.

Improvement of aerobic stability with Lupro-Mix® NA (Maize silage with 37% TM, 49 days ensiling time)

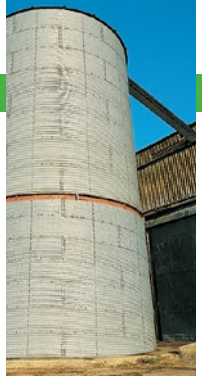
	Control (untreated)	Lupro-Mix® NA (4 l/t)
DLG score	100	100
pH-value	3.9	3.9
Silage stability (days)	3.5[a]	10[b]
Loss through post-heating (%)	15.1[a]	0.3[b]

Kalzendorf, 2011

Maize silage, treated with Lupro-Mix® NA

Maize silage, untreated

9 Products for ensiling



The following table lists the BASF products with respect to their ingredients, pH value and density.

Luprosil® is a colourless liquid with a pungent odour. It contains propionic acid as active ingredient. Luprosil® is a strongly organic acid which is caustic and has a corrosive effect on metals. Luprosil® is ideal for combating and preventing post-heating of silages. It bears the DLG Quality Symbol for this application.

With the ensiling additive Lupro-Mix® NA it is possible to produce good silage even under difficult conditions. In addition Lupro-Mix® NA prevents post-heating and improves the aerobic stability of silage. For these two fields of application the product bears the DLG Quality Symbol.

Lupro-Mix® NA is a buffered mixture of propionic and formic acid with a pH value of approx. 4. The mixing of propionic and formic acid allows an optimal effect to be achieved: fast lowering of the pH value coupled with gentle treatment of the lactic acid bacteria, combined with efficient combating of yeasts, clostridia and mold fungi.

Ingredients and pH value of the ensiling additive

	Luprosil®	Lupro-Mix® NA	Lupro-Cid® NA	Amasil® NA
State	liquid	liquid	liquid	liquid
pH value	2.3*	3.4	ca. 2.7	>2.1<3*
Density g/l (20 °C)	990–998	1207	1256	1301
Corrosiveness	+++	+++	++	++
Propionic acid (%)	99.5	38	18	
Formic acid (%)		34	54	75
Ammonia (%)				
Sodium (%)		8	8	7
Water (%)	0.5	20	20	18

+ slightly corrosive, +++ corrosive
*100 g/litre of water

The NC product Amasil® NA can completely replace the caustic formic acid that is used as an ensiling additive under difficult ensiling conditions. Although Amasil® NA is an NC product that is user-friendly (classification = irritating) and gentle on materials, it is clearly in the acidic range just below pH 3. We recommend the ensiling additive Lupro-Cid® NA, a product that is non-caustic as well, if difficult ensiling conditions require the production of big bale silage. It is a mixture comprising buffered formic acid and propionic acid. The propionic component functions to prevent the formation of mould when the silage is exposed to air.

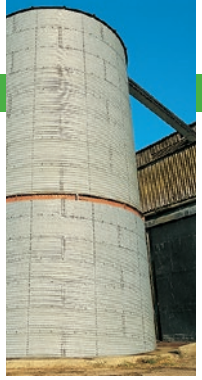
As is the case for all buffered acid products, the NC products Lupro-Mix® NA, Lupro-Cid® NA and Amasil® NA become more viscous when cooling down. Although the flow meter on the dosing apparatus still shows the same flow rate, less acid is dosed and this can lead to under-dosage. As a rough rule, if the temperature of the mentioned NC products changes by 5 °C by comparison with the temperature on the day the dosing equipment capacity was gauged, the flow rate of the dosing equipment must be gauged again under the new temperature conditions.

As a strong organic acid, Luprosil® has a caustic effect on the skin. The products Lupro-Mix® NA, Lupro-Cid® NA and Amasil® NA are not caustic, but instead are classified in the far less dangerous class ‘irritating’. Despite this, handling of all acid products calls for appropriate protective equipment, including tightly closed safety goggles. Please read carefully the topics Occupational Safety and First Aid Measures in Chapter 12 (p. 66–69).

10 Technique of using silage additives

To improve the silage quality the acid products have to be distributed as uniformly as possible in the required dose in the material to be ensiled. This is generally done by spraying the harvested material with the aid of acid-proof pumps at the chopper-type forage harvester, self-loading trailer or the CCM mill. The dosing equipment used is similar in type to that used for grain conservation. As regards the quantity checks for acid and material to be ensiled, the gauging of the dosing equipment and occupational safety measures, the tips and instructions provided for grain preservation in Chapter 5 apply here also.

Injection of liquid silage additives

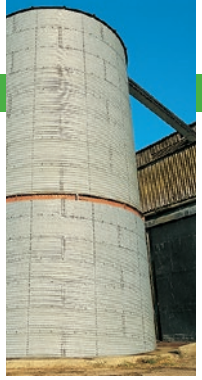


For ensiling, a pour-on method using acid-water mixes is also applied directly at the silo. The acid products are diluted with water and then sprayed or poured onto the material to be ensiled. The mixing ratio of acid product to water here is always 1 part acid to 4 parts water. Mixtures with a closer acid : water ratio (e. g. 1 part Luprosil® + 1 part water) are more aggressive and corrosive than pure propionic acid. Always wear goggles, acid-resistant protective gloves and a face mask screen for this work (see also Chapter 12, Occupational Safety). Always pour the acid into the water and never vice versa!

Acid-resistant drums in conjunction with hose and shower head, wateringcans or knapsack sprayer are used to distribute these solutions. Care should be taken to ensure that the distribution equipment does not contain any components made of corrosionsensitive metals (e. g. brass).

Silage additives are no substitute for a careful ensiling technique. Even when silage additives are used, the partially wilted green matter must be sufficiently compacted and then be covered quickly and made airtight with plastic sheeting.

11 Recommended doses for ensiling



11.1 Maize and grass silage (and comparable silages)

Silage complete treatment

For complete treatment of silage the entire feedstock is mixed with the ensiling additive. The silo is thus totally protected against post-heating. In addition Lupro-Mix® NA improves the fermentation progress. The additives are dosed depending on the dry matter content.

- **Storage of corn, whole grain, in air-tight silos:**
  0.4% Lupro-Mix® NA (4 l/t)

- **Improvement of aerobic stability of silage:**
  Grass silage: 3–4 litre Lupro-Mix® NA/t

Application rates for Lupro-Mix® NA or Luprosil® in litre per ton green matter for complete treatment

Dry matter of the harvested material	Lupro-Mix® NA l/t	Luprosil® l/t
Up to 25%	4	4
25–35%	3	5
Over 35%	4	6

Surface treatment and edge treatment of silage

Although treatment of the silo surface is no substitute for complete treatment during ensiling, if applied properly it is an effective protection measure against losses at those parts of the silo which are exposed to particular risk.

For this preferably Lupro-Mix® NA (or also Luprosil®) is best added to the last wagon loads with dosing equipment directly at the harvesting machine. The dose for the treated layers is the same as that for complete treatment.

It is also possible to pour on a mixture of Lupro-Mix® NA (or Luprosil®) and water and subsequently work this in. Since the action of Lupro-Mix® NA (or Luprosil®) only extends to the treated feed layers, it should be worked into an approx. 50 cm thick layer at the surface of the silage.

- **Recommended dose of Lupro-Mix® NA (or Luprosil®) for surface treatment:**
  The mixing ratio for pour-on solutions is 1:4 (1 litre Lupro-Mix® NA or Luprosil® is mixed with 4 litres water). The following quantities of this pour-on solution are used to treat a 50 cm thick layer of silage depending on the dry matter content.

Application rates of diluted acid for surface treatment

Dry matter of the harvested material	Lupro-Mix® NA or Luprosil®/water mixture in l/m²	Acid product in l/m²
Up to 25%	12	2.4–2.5
25–35%	14	2.8–3.0
Over 35%	16	3.2–3.5

Using Amasil® NA (and Lupro-Cid® NA) instead of Formic Acid 85 for complete treatment of silage

85% formic acid is used in colder regions as an ensiling additive for wet silages, that is, for difficult ensiling conditions. The user-friendly NC product Amasil® NA can completely replace the caustic formic acid in this application. The dose recommendation is 3 to 4.5 litres Amasil® NA/t fresh grass for complete treatment.

We recommend the ensiling additive Lupro-Cid® NA, a product that is non-caustic as well, if wet and difficult ensiling conditions require the production of big bale silage. It is a mixture comprising buffered formic acid and propionic acid. The propionic component functions to prevent the formation of mould when the silage is exposed to air. The dose recommendation is 4 to 6 litres Lupro-Cid® NA/t fresh grass for complete treatment.

11.2 Treatment in the case of post-warming

Subsequent post-fermentation and post-heating of the silage leads to nutrient losses and reduces feed intake. This phenomenon occurs frequently in the Total-Mix-Ration (TMR). Please note the special dosing tips in chapter 6.5 for this. To combat post-heating of silage which has already heated up during or after being unloaded from the feed stock, we recommend Luprosil®. Heated grain must be unloaded from the silo and spread out approx. 20 cm high. 0.5 litre Luprosil®, diluted with 2 litres water, is then poured over each square metre feed and mixed well. The silage cools down quickly and can be fed immediately after cooling without any waiting period.

The cut faces in the silo stock can also be treated with Luprosil®. 0.5 litre Luprosil®, diluted with 2 litres water, is then poured over each square metre of the cut face. After this the feed stock must be covered carefully again. During pauses in silage making Luprosil® treatment with the same application rate can be carried out to prevent heating and mold formation in the top layer of green material.

11.3 Preservation and ensilage of CCM (Corn-Cob-Mix)

When Corn-Cob-Mix (CCM) is fed during warm seasons, major problems often occur with post-fermentation, especially if the CCM was harvested with high dry matter contents. This post-fermentation characterised by heating is caused by yeasts and mold fungi. Air can infiltrate through cracks in the CCM or when it is unloaded and lead to brisk metabolic activity of the yeasts. With the access of oxygen these can multiply quickly and the consequences are nutrient losses, in some cases of up to 20%, as well as hygiene problems in liquid feeding.

With the products Luprosil® or Lupro-Mix® NA, CCM can be protected effectively against post-heating.

In practice CCM is more frequently preserved as silage. CCM is ensiled as usual in a clamp or tower silo. Lupro-Mix® NA or Luprosil® is added before or in the CCM-mill to ensure sufficient distribution. The addition of acid prevents post-fermentation in the silo stock, spoiling of the cut face and heating of the feed removed.

The following application rates of Lupro-Mix® NA are recommended as a silage additive:

Ensiling of CCM with Lupro-Mix® NA	
Storage period	**Lupro-Mix® NA**
1–6 months	0.5–0.6%
6–12 months	0.7–0.8%

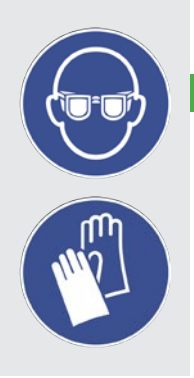
Alternatively, 0.5–0.75% Luprosil® or 0.6–0.8% Lupro-Grain® may be used as an ensiling substitute. The higher doses correspond to high dry matter content (e. g. 70% DMC).

11.4 Crushed grain silage (ensiling of moist crushed grain)

Moist crushed grain can be subjected to lactic acid fermentation just like maize silage. However, with increasing water content the lactic acid fermentation occurs more readily. This fermenting substrate also tends towards post-heating and mold formation. Protection against mould and post-heating is possible by using one of the three products Lupro-Mix® NA, Lupro-Grain® or Luprosil®.

Application rate (%) for complete treatment of crushed grain silage with Lupro-Mix® NA, Lupro-Grain® or Luprosil®		
Moisture (%)	**Lupro-Mix® NA (%)**	**Luprosil® or Lupro-Grain® (%)**
< 20	0.50	0.50
20–30	0.40	0.40
> 30	0.30	0.30

12 Occupational safety



Luprosil® causes caustic burns on the skin and mucous membranes. Luprosil® vapors irritate the respiratory tract and should not be inhaled. That is why suitable protective equipment is necessary for handling Luprosil®! In addition Luprosil® should only be used in the open or in well ventilated rooms.

12.1 First Aid measures after contact with Luprosil®

After skin contact wash off immediately with generous quantities of water. In the case of injuries apply a sterile dressing. Consult a dermatologist. Change contaminated clothing immediately.

In the case of eye contact rinse thoroughly at once for 15 minutes under running water with the eyelids spread open. Consult an ophthalmologist. After swallowing rinse out the mouth immediately and drink large quantities of water. Seek medical assistance.

In the event of feeling unwell after inhalation, consult a physician. In the field of Occupational Safety three hazard stages which can occur during handling of and working with Luprosil® are described below and the necessary protective measures are explained.

12.2 Major accident

Relatively large quantities of Luprosil® are spilled and wide-scale wetting of the ground results. For example a 200 litre drum or a 1,000 kg container leaks during storage or Luprosil® packages are heavily damaged during transport. In the case of a major accident a complete protective suit must be used. At propionic acid concentrations of below 1% by volume a gas filter of Type 3A3 can be used, but respiratory protection independent of the ambient air is preferable (e. g. compressed air breathing apparatus). In cases in which large quantities of product spill, the fire brigade must be called in.

12.3 Protective measures when working with undiluted Luprosil® products (e.g. filling and transfer operations) and with Luprosil®-water mixes

The following work situations are described:

- opening and closing the package and connecting to dosing equipment,
- setting (gauging), operating and flushing the dosing pumps and remaining in the direct vicinity of dosing equipment which is in operation with acids,
- filling the acid into watering cans (or other containers) and producing and using Luprosil®-water mixtures,
- spraying Luprosil® or a Luprosil®-water mixture on cut silage faces.
- With regard to respiratory protection remaining in an atmosphere of acid vapors (up to 0.1% by volume = 1.000 ppm) formed during grain preservation in poorly ventilated rooms or during blower conveyance of freshly preserved grain is included here.

The following protective measures are necessary for these work situations:

- **Body protection**
  Wear gloves and an acid-resistant apron, e. g. made of PVC. If no gloves with long cuffs are available, extra cuffs should be used.

  The following glove materials are resistant to propionic acid (concentrated):
  PVC: up to 4 hours
  Polychloroprene (CR): over 8 hours
  Nitrillatex (NBR): over 8 hours
  Butyl rubber: over 8 hours

  These data were ascertained in accordance with EN 374.

  Rubber boots must be worn. They should be high enough that the acid-proof apron hangs down several centimetres below the tops and no acid can run down from the apron into the rubber boots.

- **Eye protection**
  Always use goggles. If splashes are to be expected (always when filling) you should also use a face mask screen (to DIN 51 822).

  In the field (e. g. at the chopper), sufficient water must be available for rinsing the eyes for 15 minutes if they accidentally come into contact with the acid product. We recommend special eye rinses from lab supplies, for instance the product Previn®.

- **Respiratory protection**
  A half mask with A-filter for organic gases and vapors is suitable. This filter can be used in the class up to 0.1% by volume (= 1.000 ppm). Recommended TYPE: A1 to EN 405, in the case of dust development also as Type A1 P1.

12.4 Protective measures when dealing with freshly preserved harvested crops

Contact with grain immediately after treatment with acids or with silage over which Luprosil® has been freshly poured. In these situations it is advisable to wear protective gloves (see above). Conventional work clothing is sufficient as body protection. Sensitive persons can use respiratory protection with a half mask with A-Filter (TYPE: A1 to EN 405).

In contrast to Luprosil®, the products Lupro-Grain®, Luprosil® NC, Lupro-Mix® NA, Lupro-Cid® NA and Amasil® NA are not caustic and are only classified as “irritating”. However they can cause grave eye damage. Protective gloves (material see above) and tightly closed goggles are recommended wear for handling these products. Work clothing is sufficient for body protection. The vapor pressure of these products is lower than that of propionic acid. According to the Safety Data Sheet respiratory protection is not necessary. In case of need, however, the half mask with A-Filter (TYPE: A1 to EN 405) as described above for use with propionic acid can be used.

13 Appendix with sources

The systems listed below have not been individually tested by BASF. This is a neutral reference source and we do not guarantee its completeness.

Dosing system for preservatives

Ziegler Harvesting
Schrobenhausener Straße 74
D-86554 Pöttmes
Tel.: +498253/99970
Fax: +498253/999747
www.ziegler-harvesting.com

Agravis Technik Holding GmbH
Hellegraben 19
D-48231 Warendorf
Tel.: +492581/6354-0
Fax: +492581/61250
www.getreidekonservierung.de

Schindler – Anlagenbau Gerätebau
Elmenhorster Straße 11
D-18510 Absthagen
Tel.: +4938327/4310
Fax: +4938327/40117
www.schindler-anlagenbau.de

sera GmbH
Sera-Straße 1
D-34376 Immenhausen
Tel.: +495673/999-00
Fax: +495673/999-01
www.sera-web.com

H. Wilhelm Schaumann GmbH
An der Mühlenau 4
D-25421 Pinneberg
Tel.: +494101/2000
Fax: +494101/2299
www.schaumann.de

Sila GmbH
Kunststoffstr. 3
D-06749 Bitterfeld
Tel.: +493493/73677
Fax: +493493/73678
www.silaspray.de

Dosing system for silage

Ziegler Harvesting
Schrobenhausener Straße 74
D-86554 Pöttmes
Tel.: +498253/99970
Fax: +498253/999747
www.ziegler-harvesting.com

Schindler – Anlagenbau Gerätebau
Elmenhorster Straße 11
D-18510 Absthagen
Tel.: +4938327/4310
Fax: +4938327/40117
www.schindler-anlagenbau.de

Agravis Technik Holding GmbH
Hellegraben 19
D-48231 Warendorf
Tel.: +492581/6354-0
Fax: +492581/61250
www.getreidekonservierung.de

Sila GmbH
Kunststoffstr. 3
D-06749 Bitterfeld
Tel.: +493493/73677
Fax: +493493/73678
www.silaspray.de

Dosing system for the permanent supplementation of Lupro-Mix® NA

Hingerose Ltd.
5 Ryder Court, Saxon Way East
Corby, NN 18 9NX
Northamptonshire
Tel.: +441536461 441
Fax: +4401536461 600
info@hingerose.co.uk

Schindler – Anlagenbau Gerätebau
Elmenhorster Straße 11
D-18510 Absthagen
Tel.: +4938327/4310
Fax: +4938327/40117
www.schindler-anlagenbau.de

Sila GmbH
Kunststoffstr. 3
D-06749 Bitterfeld
Tel.: +493493/73677
Fax: +493493/73678
www.silaspray.de

Mechanical hand pumps for easy withdrawal of acid product from the Luprosil® barrels (e. g.)

Agravis Raiffeisen AG
Industrieweg 110
D-48155 Münster
Tel.: +49251 6822 289
Fax: +49251 6822 008
www.getreidekonservierung.de

Acid-proof paints for silos and floors (grain storage and silage)

IRSA Lackfabrik Irmgard Sallinger GmbH
An der Günz 15
D-86489 Deisenhausen
Tel.: +498282/89440
Fax: +498282/894444
www.irsa.de

Agravis Raiffeisen AG
Industrieweg 110
D-48155 Münster
Tel.: +49251 6822 289
Fax: +49251 6822 008
www.getreidekonservierung.de

Breathing masks and protective equipment

PM Atemschutz GmbH
Willicher Damm 99
D-41066 Mönchengladbach
Tel.: +492161/40290-0
Fax: +492161/40290-20
www.pm-atemschutz.de

KCL GmbH (Honeywell Safety Products)
Am Kreuzacker 9
D-36124 Eichenzell
Tel.: +496659/87-0
Fax: +4966 59/87-129
www.kcl.de