

Eco-efficiency Analysis

Animal Nutrition

 **BASF**

The Chemical Company

Eco-efficiency Analysis

> Considering the environmental impact

Without doubt we are operating in a fast-moving world in which established positions are repeatedly re-examined. More and more modern consumers are not willing to accept a product just because of its quality alone. Excellent quality as such is seen as a mandatory fact. Thus, arguments like social and ecological acceptance are gaining importance.

In future the sustainability of products and the adequate production systems based on their total lifecycle will become more and more important.

The eco-efficiency analysis looks at the complete lifecycle of a product: from raw material extraction to recycling or disposal.

In the development and optimisation of products and processes, eco-

efficiency analysis makes it possible to consider total costs and ecological impact side by side and to select the most ecoefficient alternative.

In 1996 eco-efficiency analysis was developed primarily as an in-house tool to optimise BASF product lines. It is a strategic instrument which assists BASF in identifying products, combining the optimum in application with good environmental performance at the best possible price. To date, about 250 different products and manufacturing processes have been analysed using the new method.

Results help to improve products and processes, to define research and development targets, and to decide on future investments.

Eco-efficiency analysis is also applied in order to help our customers con-

serve resources. For this purpose, economic and ecological advantages and disadvantages of different product or process solutions fulfilling the same function for customers are compared with each other. By doing this, the method goes beyond the isolated consideration of in-house products and also includes alternatives from outside BASF. Thus, all relevant decision factors are analysed, while concrete customer benefits are always the focus of attention.

Eco-efficiency analysis forms part of the efforts made by BASF to bring its entrepreneurial activities in line with the model known as "Sustainable Development". This analysis is fully recognised and certified by independent ecological institutes.

> Taking a comprehensive view of the product

Eco-efficiency analysis assesses the lifecycle of a product or manufacturing process from “the cradle to the grave.” To demonstrate the principles of an eco-efficiency study, an example from daily life is taken: buying a car. In this real data-example all cars have the same convenience for the user, but differ in engine technology.

When a consumer is going to buy a car he may consider various factors. Besides some emotional aspects mainly the sales price might influence the decision.

Regarding the sales price car E is the most expensive. Thus one would prefer a similar, but cheaper car like A, B, C, D (Fig. 1). Considering the total costs during the entire lifecycle, car E improves its position. According to the new grading, all cars have more or less the same ranking (Fig. 2).

What does the picture look like, if the environmental impact of the cars is taken into account such as consumption of energy and raw material, as well as emissions, risks, and toxicity potentials in the production processes?

Fig. 1: Conventional grading based on sales price

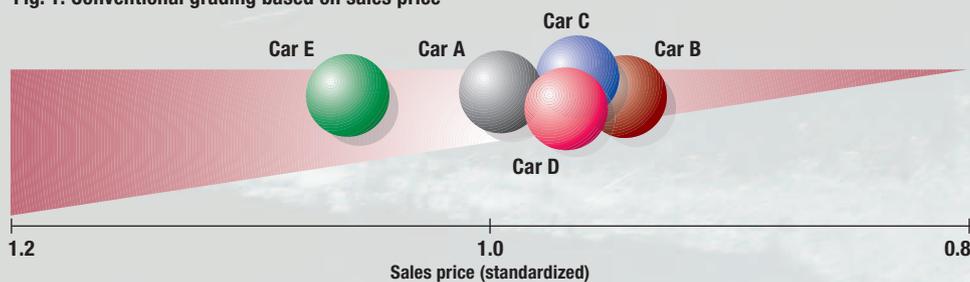


Fig. 2: Grading in view of the costs during the entire life cycle

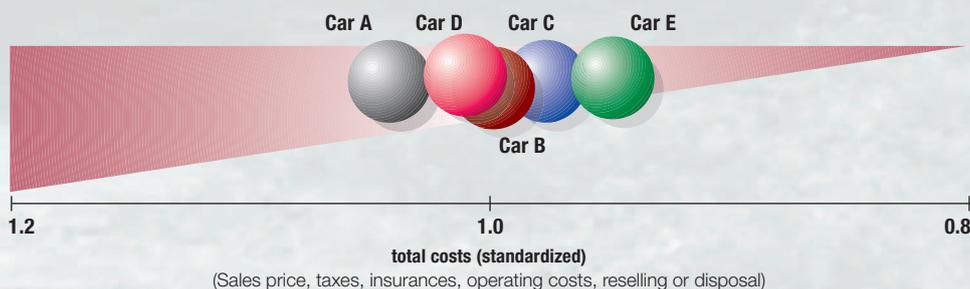
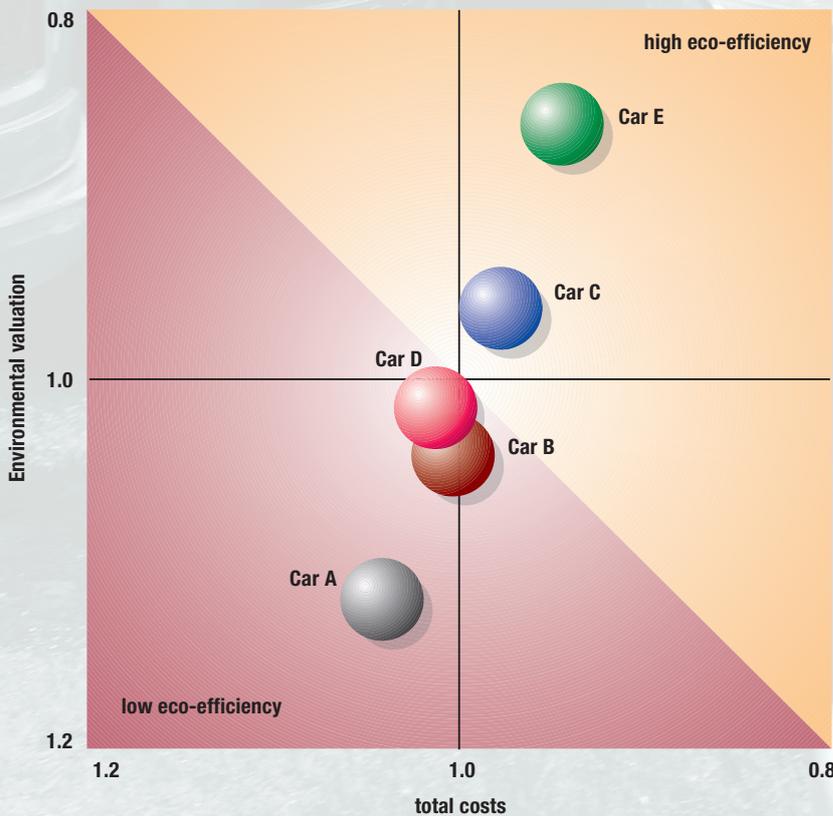


Fig. 3: Ecoefficiency portfolio (Grading based on eco-efficiency)*



- * 1. Energy use (25%)
 2. Raw material use (25%)
 3. Emissions (20%)
 4. Toxicity (20%)
 5. Risk potential (10%)

Cars to compare

- car A: European 1.6 l / 66 kw, petrol (old technology)
- car B: Japanese 1.6 l / 66 kw, petrol (standard technology)
- car C: European 1.6 l / 55 kw, petrol (standard technology)
- car D: European 1.8 l / 66 kw, petrol (standard technology)
- car E: same as car D but 1.9 l / 66 kw (most modern diesel technology)

All cars are of medium size, used for 10 years and 200,000 km.

A decision based on environmental parameters relegates car A to the last place due to its out-of-date engine technology, places the cars B, C and D in the midfield and favours car E.

In view of the different results the crucial question arises: What is the best basis to decide on? The eco-efficiency analysis helps to make an economically as well as ecologically sound decision. It examines and evaluates environmental and cost factors in one analysis. Car A positioned in the lower left corner has a low eco-efficiency, while car E in the opposite corner combines lower total costs with ecofriendliness, which means high eco-efficiency and a high attractiveness to buy it (Fig. 3).

In this example the eco-efficiency analysis results in a decision which would never have been made, if the customer had been looking only at the sales price. For the manufacturers of such cars this is also a very important result. It demonstrates, that investments in the development of an advanced ecofriendly engine technology can improve competitiveness, even at higher sales prices.

> The ecological fingerprint after BASF: Identification of aspects influencing the environmental impact



BASF has developed a special kind of graphic representation in order to easily visualise the environmentally relevant parameters of products or processes and compare them: the BASF ecological fingerprint. It supplies us with a picture of the relevant environmental impact according to six main categories:

- Raw material utilisation
- Surface use
- Energy consumption
- Emissions to air, water and soil
- Toxicity potential
- Risk potential

BASF is preparing to add the social dimension into this as well.

The different parameters are determined quantitatively and then weighed by a so-called relevance factor and a social factor. The relevance factor takes into account the contribution of the analysed parameter to e.g. total emissions or energy consumption. The social factor represents to which extent the public opinion is interested in this certain environmental problem.

After statistical normalisation and weighting of the criteria, the calculated values are entered on the axes of the ecological fingerprint. With this method the advantages and disadvantages of the analysed alternatives can be compared with each other in each category.

The alternative rated with value 1, which is the most unfavourable in the respective category, represents the least favourable option. The closer the alternative is to the centre of the graph, the more favourable it is rated.

The axes are independent of each other so that an alternative, e.g. with very low energy consumption, may be less favourable regarding the emissions for example (Fig. 4).

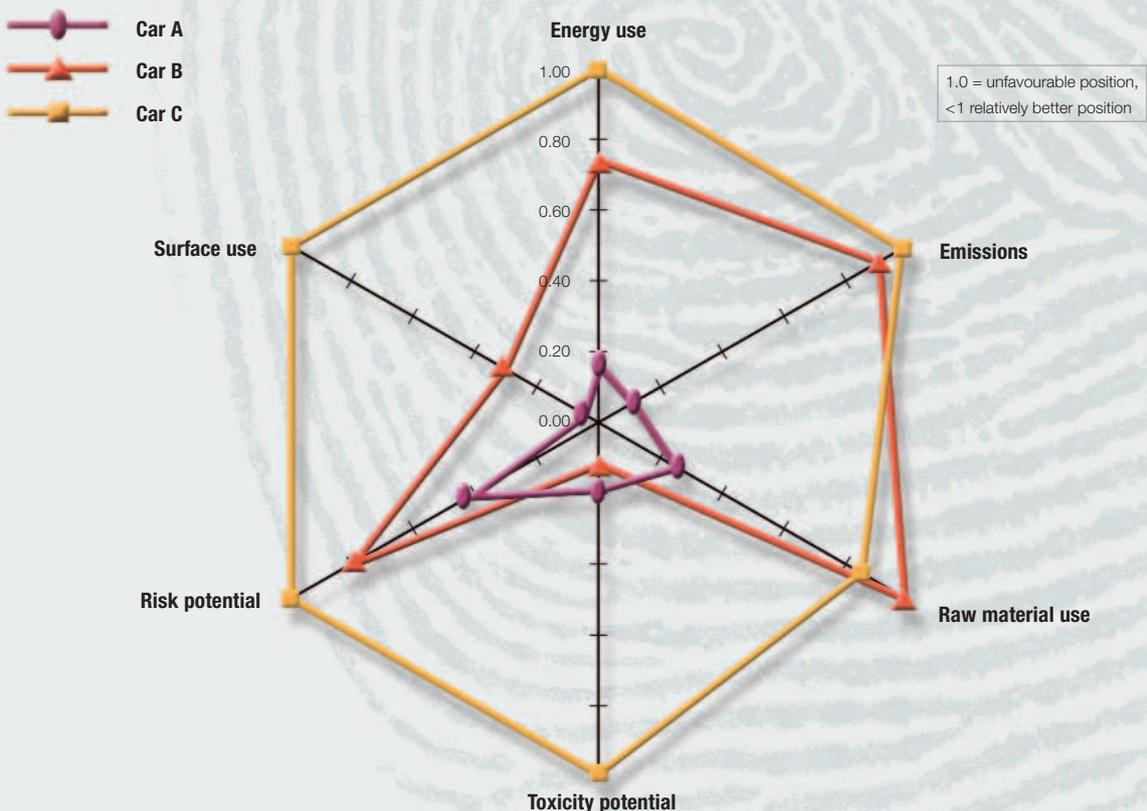
Like a human fingerprint, which can be assigned unequivocally to an individual, the ecological fingerprint unequivocally refers to a defined product, which is clearly defined by its composition, production method and range of application. Whereas the characteristic pattern of lines of a human fingerprint usually remains

unchanged throughout life, the ecological fingerprint is rather a snapshot. As all relations in the fingerprint are relative to each other, the change of one parameter results not only in the change of this specific parameter for one product but also for the competing products as their relative favourability changes as well in this respect. Further developments in process technology leading to a more efficient use of raw materials, for instance, will change the product's impact on the environment and hence its relative advantage over similar products and the

corresponding graphic representation. Likewise changes in the assessment of individual parameters such as the emission of toxic substances or risks of accidents will influence the diagram.

The ecological fingerprint allows a clear and yet detailed comparison of products or processes, which appear to be very similar at first sight. This method allows to quickly identify parameters with an adverse effect on the environment and to find clues, in which areas improvements are required in order to optimise the overall system efficiently.

Fig. 4: Ecological fingerprint



> Criteria employed in eco-efficiency analysis



Energy use

The energy consumption is determined for the whole life cycle of the product. It sums up all fossil and regenerative energy sources based on their maximum feedstock. This includes coal, oil, gas, brown coal, nuclear power, water power, organic substances and others.



Emissions

Air, soil and water emissions are seen jointly. They are based again on the whole life cycle of the product and its preliminary stages.



Raw material

This category takes into account the quantity of all raw materials involved in the examined process. Additionally these amounts are weighted according to the limited availability of the resource. For regenerative products a sustainable practice is taken into account.



Surface use

Also soil represents a limited resource. Although soil is not consumed like raw material, it may deteriorate or decrease in its functionality depending on the kind, extent and intensity of surface use. In this parameter not only the acreage but also the soil quality is considered.

Toxicity potential

The evaluation of the toxicity potential follows an objective scheme developed by BASF scientifics. It is based on regulations for hazardous substances. All preliminary stages of a product are considered as well as the product itself.



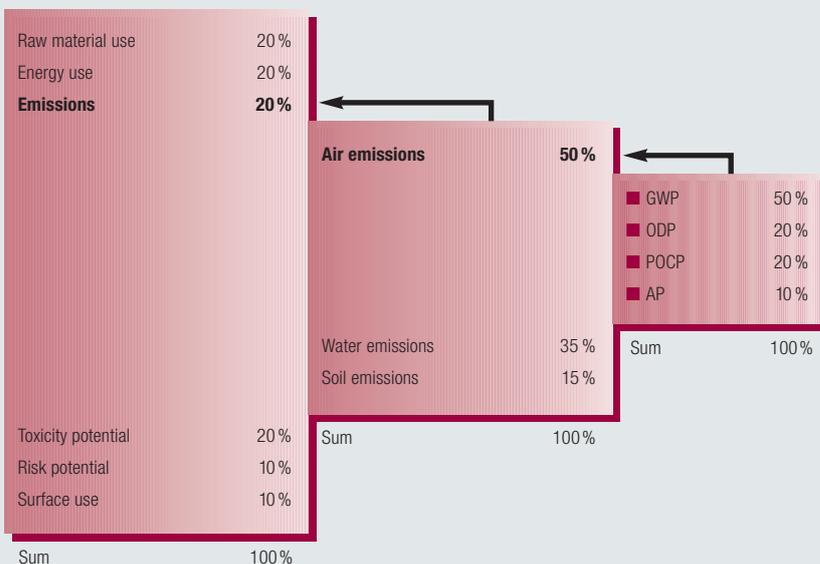
Risk potential

This parameter evaluates the risk of accidents such as fire, explosions, road accidents, or contamination of sales products. For all hazards their severity and probability are taken into account.



Fig. 5: Scaling scheme for the ecological footprint – Base case

Importance (%)



GWP = global warming potential; ODP = ozone depletion potential; POCP = photochemical ozone creation potential; AP = acidification potential

Weighting of parameters

The individual values in the ecological footprint are affected by what is called relevance factors. These state how strongly individual criteria flow into the overall environmental pollution, i.e. how, for example, the ozone destruction potential is weighted relative to the greenhouse warming potential. On the basis of public opinion polls this weighting also takes into account the importance which society attaches to the different forms of environmental pollution. Thus, both qualitative factors influenced by society as well as quantitative factors based on statistical measures are used.

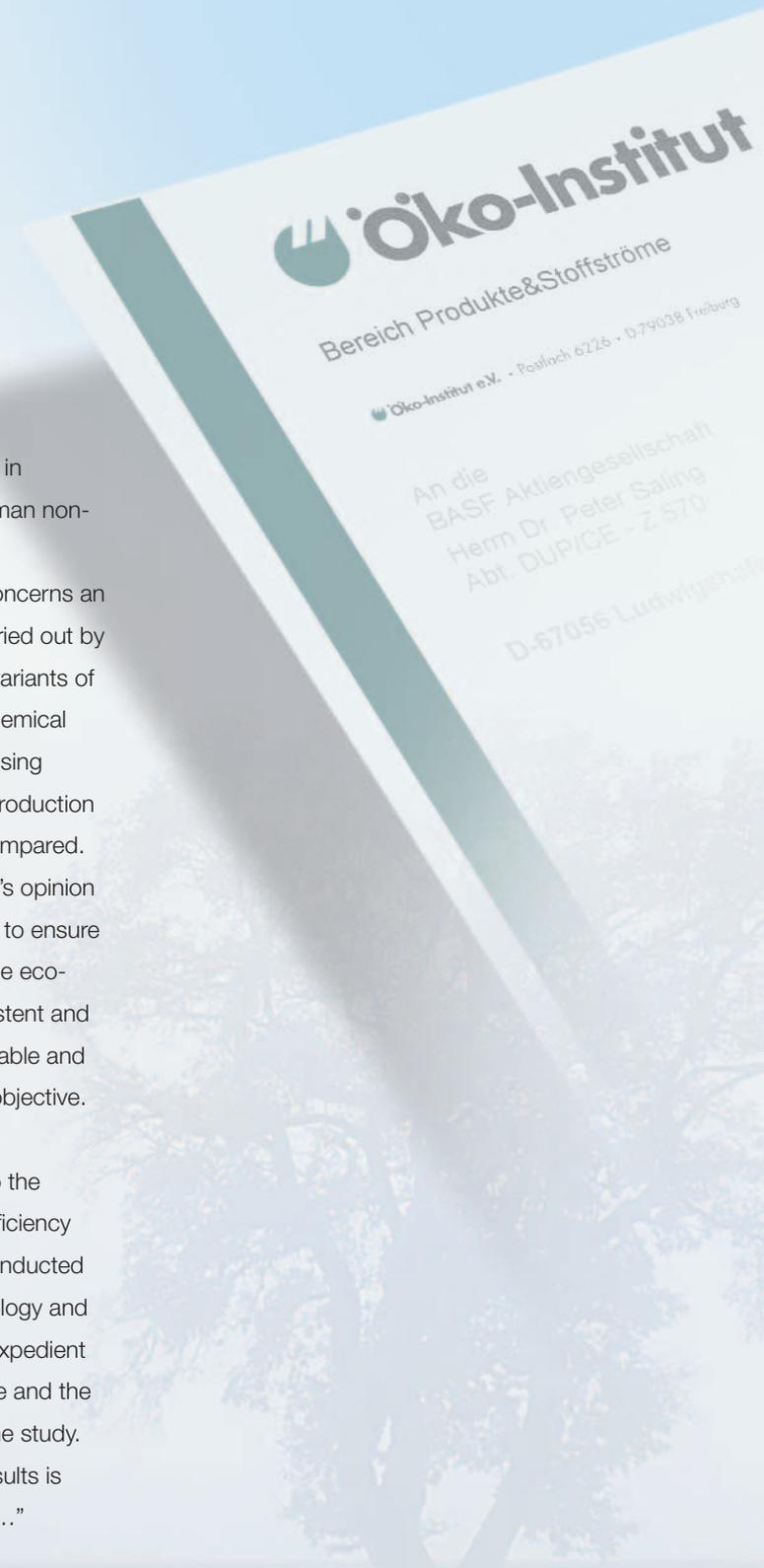
> Expert Opinion

BASF's eco-efficiency analysis was carefully examined and evaluated by independent institutes. The overall process was certified by the Rhineland Technical Surveillance Association in 2002.

Experts of the Öko-Institut in Freiburg, a registered German non-profit association, say:
“...This expert's opinion concerns an eco-efficiency analysis carried out by BASF AG, in which three variants of astaxanthin production (chemical synthesis, biotechnology using yeasts / fermenters, and production from algae / ponds) are compared. The purpose of this expert's opinion commissioned by BASF is to ensure that the methodology of the eco-efficiency analysis is consistent and that the data used are suitable and expedient as regards the objective.

Öko-Institut e. V. comes to the conclusion that the eco-efficiency analysis presented was conducted with a consistent methodology and that the data applied are expedient with regard to the objective and the framework examined by the study. The presentation of the results is largely clear and plausible...”

Summary of a report, authors: Dipl.-Ing. Carl-Otto Gensch (Project Leader), Dipl.-Ing. (FH) Kathrin Graulich, Dr. Jennifer Teufel (all from: Öko-Institut e. V., Geschäftsstelle Freiburg, 79308 Freiburg, Germany)



Eco-efficiency Analysis of Feed Grain Preservation

Animal Nutrition



The Chemical Company



> Focus on feed grain preservation

Grain and other feedstuffs are naturally contaminated with fungi, yeasts, and bacteria. If these microorganisms find favourable conditions during storage they can rapidly multiply, leading to mycotoxin formation, a decrease in nutritional value, and spoilage of the grain. Adequate countermeasures are critical to preserve the harvested grain if the moisture content exceeds a critical level of about 14 %.

There are essentially three approaches to preventing spoilage and loss of nutritional value of feed grains during storage. This eco-efficiency study presents a detailed comparison of the competing methods and helps farmers make the right investment decision.

The following approaches to preserving feed grain were analysed:

- chemical treatment with Luprosil® or Lupro-Grain®
- drying
- airtight storage

This eco-efficiency study takes into consideration all the relevant parameters of these processes, from the production of material and equipment to the feeding of the preserved grain to farm animals. All calculations of resource utilisation, energy consumption, emissions, toxicity, and potential risk were performed for a “baseline case”, which was defined as the preservation of 100 kg of feed grain containing 20 % moisture after harvesting

for a storage time of six months. An annual preservation capacity of 100 tonnes is assumed.

BASF offers two propionic acid products for reliable grain preservation: Luprosil® and Lupro-Grain®. Luprosil® is pure propionic acid, while Lupro-Grain® is partially neutralized. Farmers appreciate the rapid and reliable effect of propionic acid on detrimental microorganisms. Chemical treatment of the grain can be done easily on the farm, offering great flexibility and resulting in low procurement costs (Fig. 1).

Fig. 1: Definition of feed grain preservation with propionic acid (Luprosil®, Lupro-Grain®)

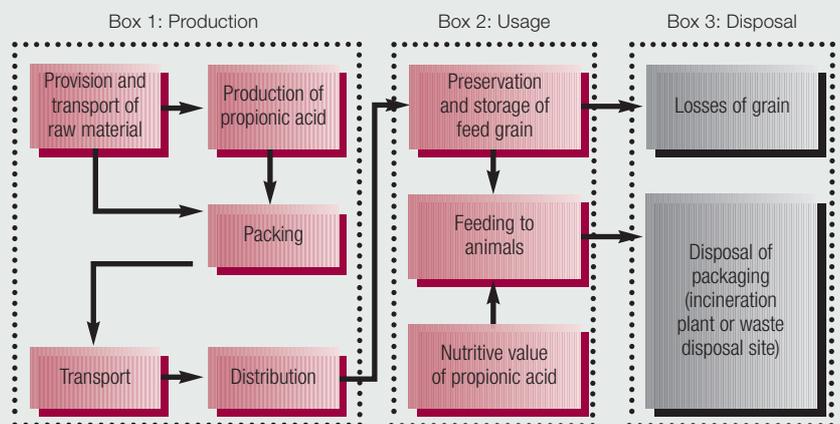
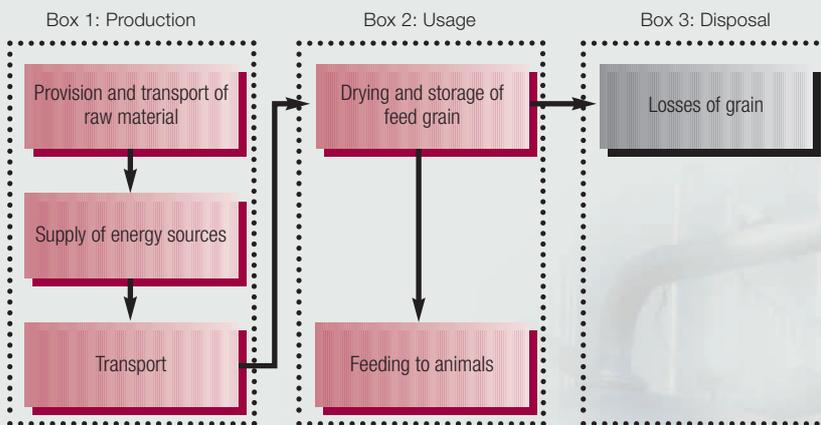
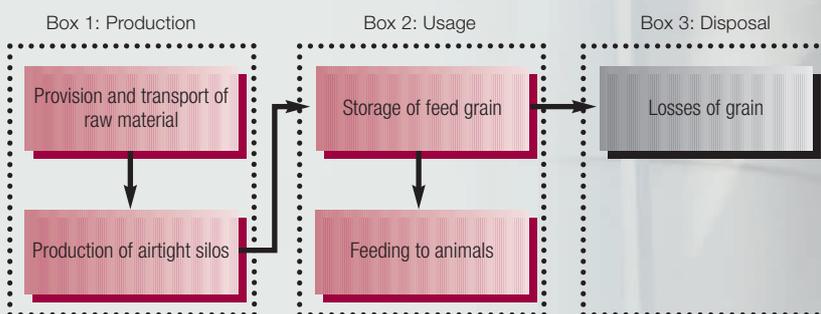


Fig. 2: Definition of feed grain drying



Batch drying and continuous-flow drying are common technical solutions for decreasing the moisture content to 14 %, the critical limit for storage of most types of grain. Continuous-flow drying is frequently preferred when large amounts of grain need to be processed. In this study, calculations were performed with oil as a source of energy (Fig. 2).

Fig. 3: Definition of feed grain storage in airtight silos



The storage of feed grain in airtight silos prevents contact with oxygen, which is responsible for the activity and multiplication of undesirable aerobic microorganisms (Fig. 3).

> Looking at economic aspects

A calculation of the total costs to the farmer of the different preservation techniques was performed (Fig. 4). This calculation takes into account both fixed and variable costs, as well as other related costs, such as costs of disposal of empty acid cans and savings in feed costs resulting from improved feed conversion ratios when feeding acid-treated grain. Normalizing of the costs allows for a clear comparison of the analysed processes (Fig. 5).

Fig. 4: Detailed specification of costs

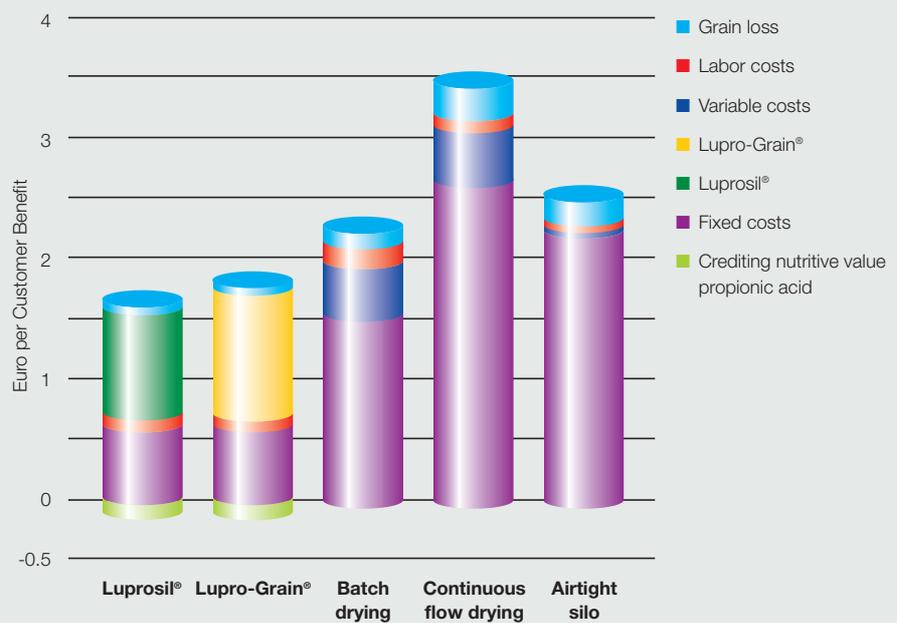
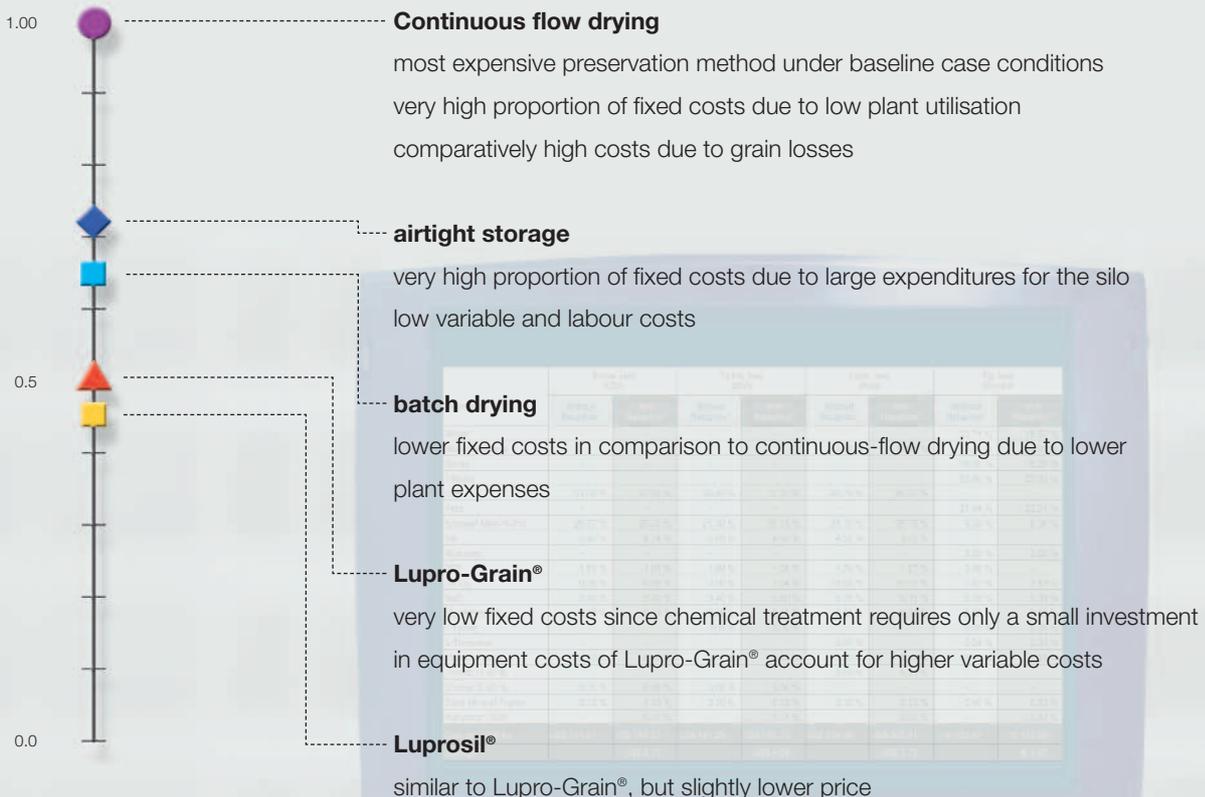


Fig. 5: Comparison of normalised costs

Normalised costs



> The ecological fingerprint of Luprosil® and Lupro-Grain®

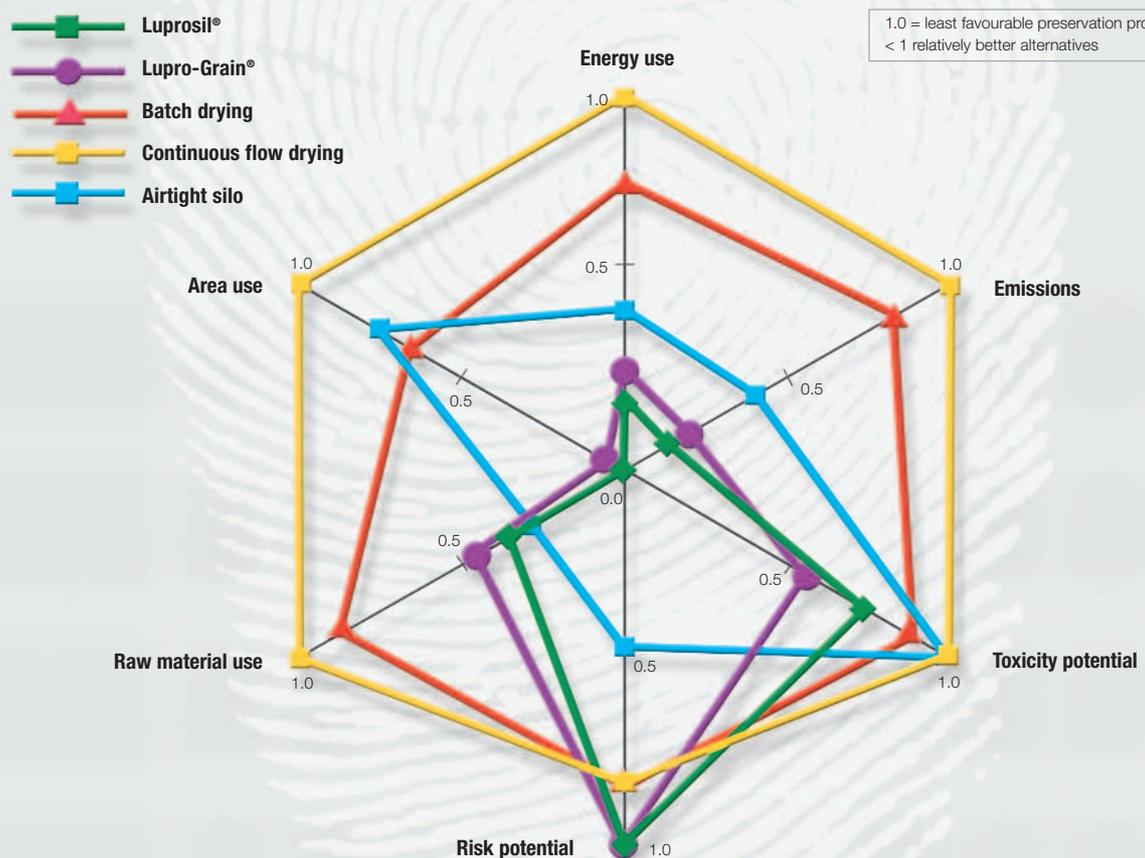
The ecological fingerprint provides a visual picture and compares the environmentally relevant parameters of the feed grain preservation methods being analysed (Fig. 6). These include the following:

- energy consumption
- emissions to air and water
- raw materials utilisation
- area utilisation
- toxicity and risk potential.

In terms of energy and raw materials consumption, both drying methods were assessed as poorest as they require high amounts of oil for heating. Grain drying and airtight storage can both result in high losses of grain leading to relatively high emissions of nutrients into surface and ground water.

Higher levels of contamination with detrimental microorganisms and their mycotoxins in grain that is dried or stored in airtight silos contributes to the poor rating of these processes in the category of toxicity. The relatively high potential risk of Lupro-Grain® and Luprosil® is due to the caustic character of propionic acid.

Fig. 6: Ecological fingerprint of Luprosil® and Lupro-Grain®



> Detailed Analysis: Raw material and area utilisation

Raw material utilisation

Oil consumption is the most common use of raw materials for feed grain preservation. The drying processes require considerable amounts of fuel

for heat production. Due to limited reserves of this non-renewable resource, the consumption of oil is rated higher than that of other raw materials.

Gas is used mainly for power generation, but also for the chemical synthesis of ammonia, which is an important component of Lupro-Grain®.

Fig. 7: Consumption of raw material

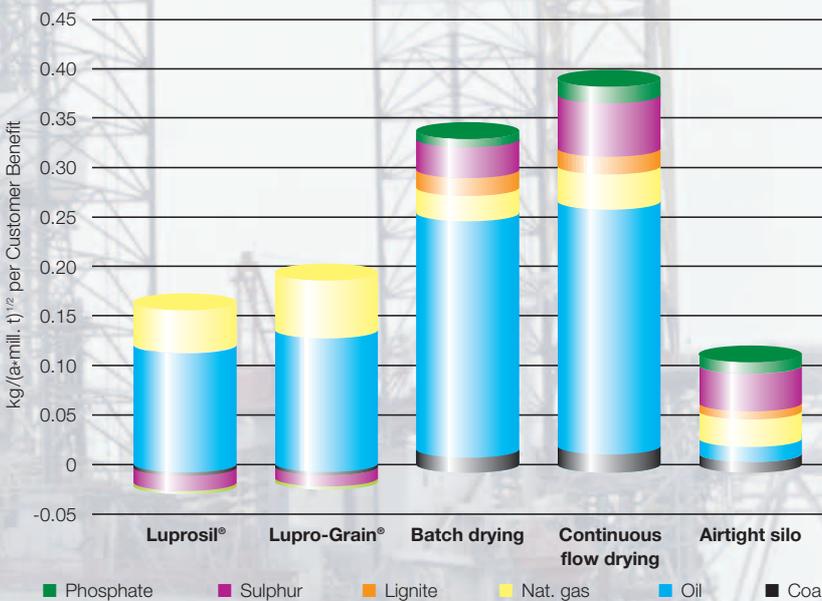
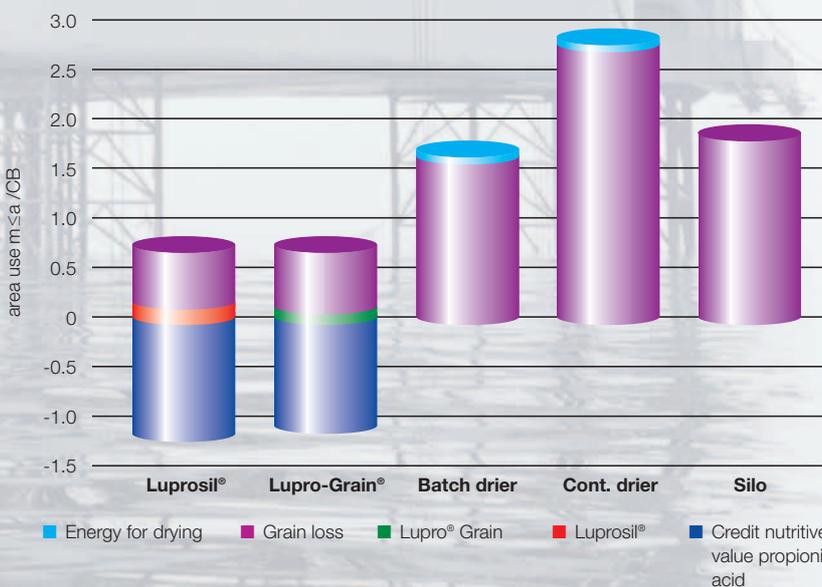


Figure 7 shows that airtight storage of grain is the best method in terms of conservation of resources. Only small amounts of raw materials are required for steel production.

* All raw materials are weighted according to the limited availability of the resource

Fig. 8: Area Use



Area utilisation

Cereal cultivation is area intensive. Thus the alternatives with highest loss of grain, with the greatest need for additional cultivation to reach the customer benefit of 100 t/a, demonstrate the lowest performance in this impact category. The Luprosil® and Lupro-Grain® alternatives have an additional credit in area use due to the nutritional value of the propionic acid, which lowers the feed amount grain needed by the animals.

> Energy consumption

As mentioned before in the context of raw materials consumption, the drying processes require a large heat energy supply to reduce the moisture content of the feed grain (Fig. 9).

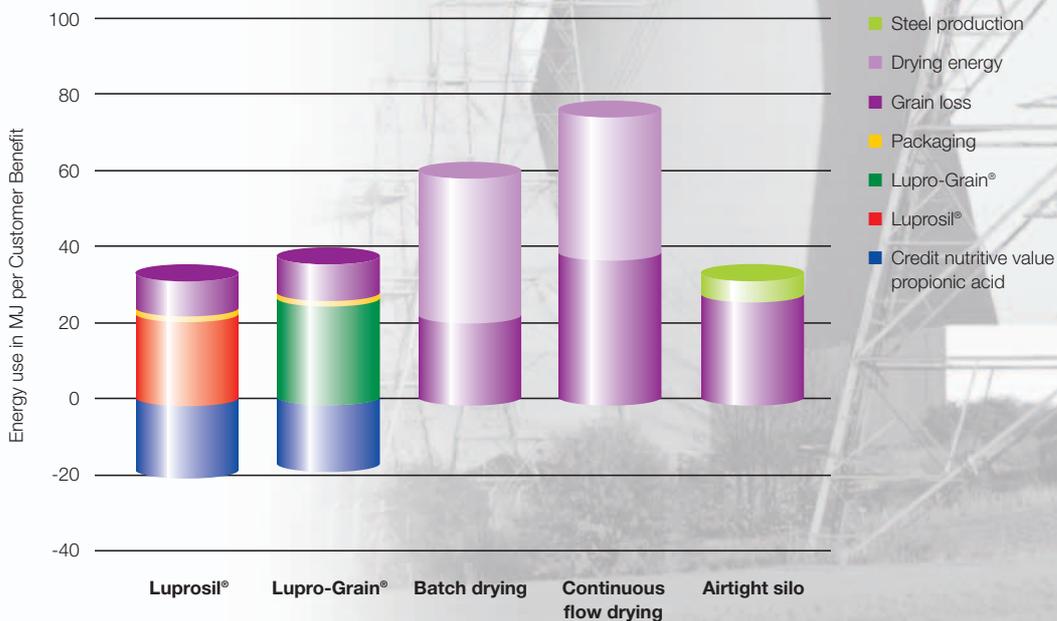
All preservation treatments are inevitably associated with some losses of grain to a different extent. Calculated in terms of energy, grain

losses increase the energy consumption of the drying processes and airtight storage, while the lower average grain loss of 0.5 % with chemical treatment has only a moderate influence.

The chemical synthesis of Lupro-Grain® and Luprosil® requires considerable amounts of energy. However, the

chemical energy in their active ingredients, mainly propionic acid, which is added to the grain for preservation purposes, is not lost but can be used physiologically by the animals. These savings in feed grain energy are included in the calculation.

Fig. 9: Energy use



> Emissions

Emissions to water

The cultivation of grain is associated with the problem of erosion. Erosion results in a significant release of nutrients and other materials into the water. Accordingly, drying and airtight storage preservation methods, which are high in grain losses, are particularly implicated in these water emissions.

On the other hand, chemical treatment with Luprosil® or Lupro-Grain® is not only associated with low grain losses, but also helps conserve grain in feeding farm animals due to the nutritional energetic value of propionic acid. This tends to decrease the extent of water emissions.

Air emissions

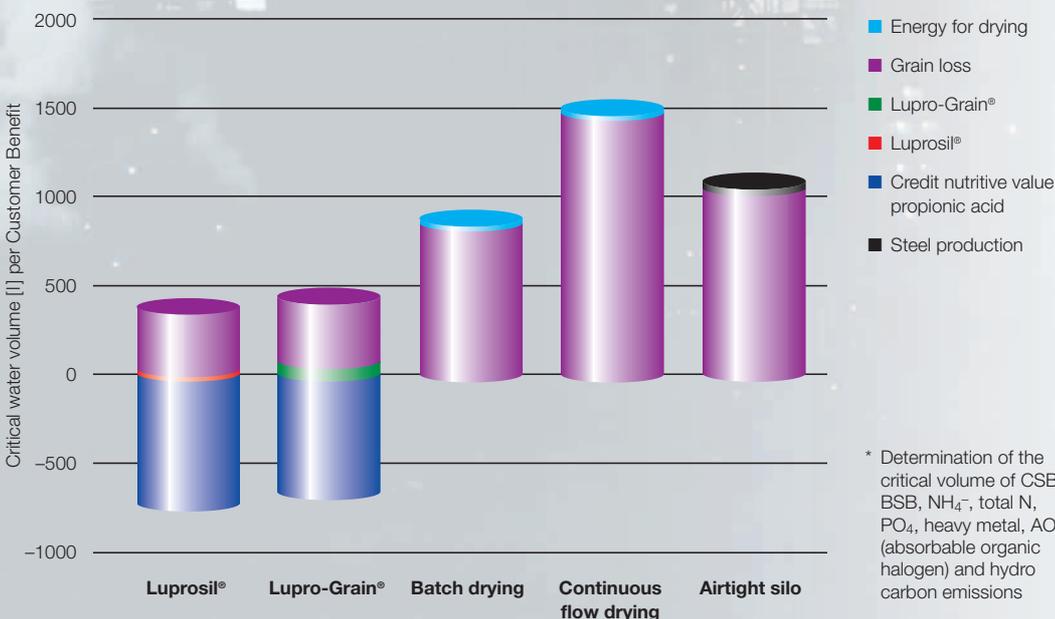
The different gases released in association with the processes compared in this study were recorded separately and evaluated according to their environmental impact. The categories of effects examined in this context are photochemical ozone creation ("summer smog"), acid rain, and greenhouse potential.

In the case of chemical treatment with Luprosil® and Lupro-Grain®, most air emissions are related to the chemical synthesis of the acid. The air emissions that occur over the course of the drying processes are associated with the high usage of oil

for batch drying and continuous-flow drying. These emissions occur in association with oil production and refining and when fuel is burned for heat production.

The production of steel for silos for airtight storage causes only low levels of air emissions, but again the ratings are influenced by grain losses, especially the acid rain potential. Feed grain savings resulting from the use of Luprosil® or Lupro-Grain® for preservation are a clear advantage for the chemical treatments.

Fig. 10: Water emissions*



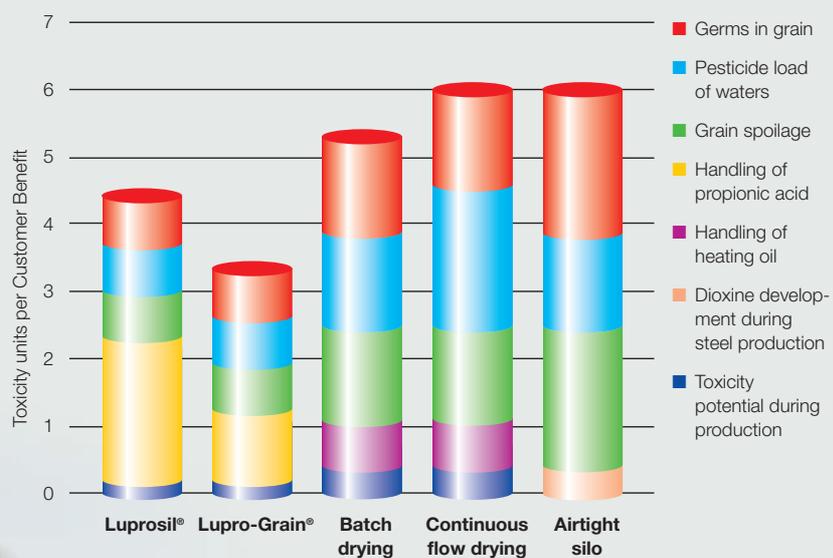
* Determination of the critical volume of CSB, BSB, NH₄⁻, total N, PO₄, heavy metal, AOX (absorbable organic halogen) and hydro carbon emissions

> Toxicity and potential risk

Toxicity potential

The toxicity potentials of the different processes are clearly influenced by the reliability and success of the resulting preservation. High levels of contamination with microorganisms and mycotoxins represent health risks. They occur more often with drying and airtight storage than with the chemical treatments. The toxicity factor “pesticides” is related to grain cultivation, and the quantity depends on the actual extent of grain losses within each preservation process. When comparing the two acid products, Lupro-Grain® has the advantage of being non-caustic to the user (Fig. 11).

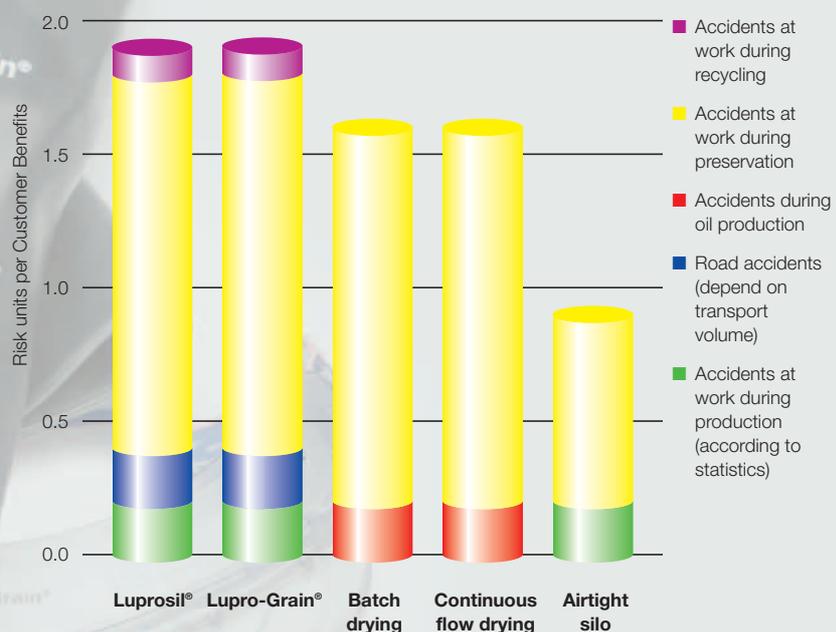
Fig. 11: Toxicity potential



Potential risk

The assessment of the potential risk focuses on work-related accidents occurring during the preservation process itself. Industrial accidents occurring during oil extraction, steel production, or acid synthesis are also taken into account. Chemical methods of grain preservation carry the risk of roadway accidents during transportation of materials and accidents at the site of recycling (Fig. 12)

Fig. 12: Risk potential



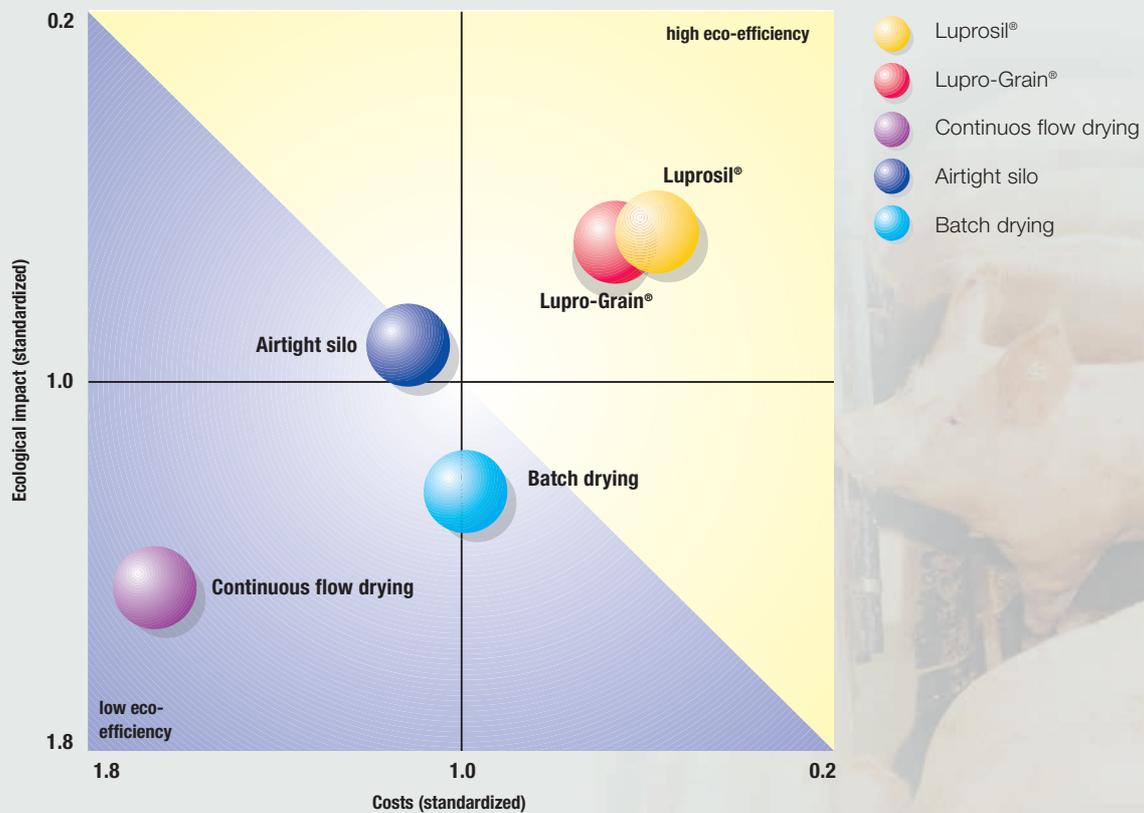
> The eco-efficiency portfolio

Preservation of 100 tonnes grain per year

For the final eco-efficiency portfolio of the alternative preservation methods, the costs were calculated against environmental positions and plotted together in a diagram.

The information provided in the portfolio is a snapshot reflecting the relative advantages and disadvantages of the approaches being analysed under the conditions of the base case (Fig. 13).

Fig. 13: Eco-efficiency portfolio of feed grain preservation

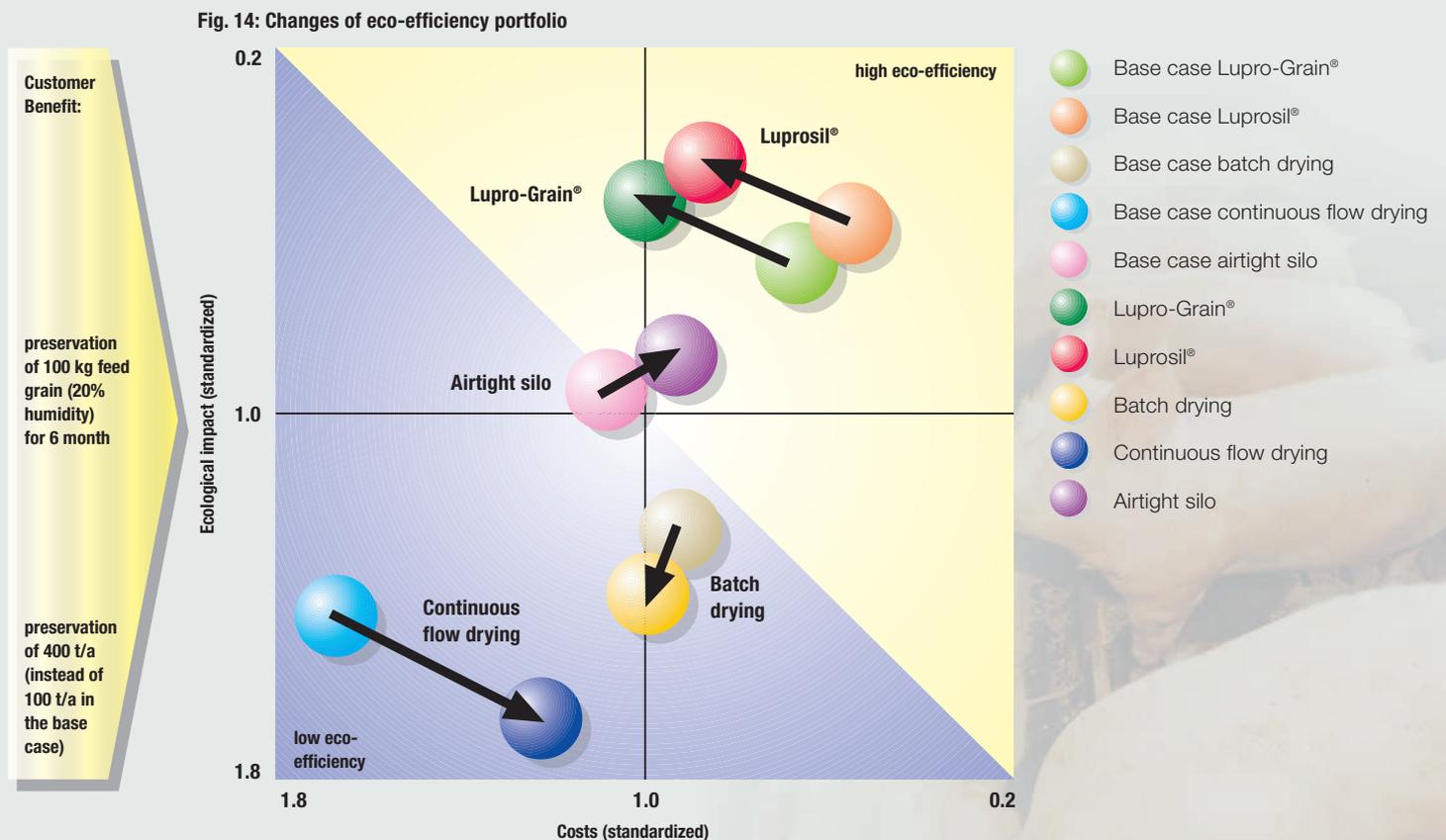


> The portfolio under changed conditions

Preservation of 400 tonnes grain per year

In the base case an annual throughput of 100 t/a grain was assumed. Luprosil® and Lupro-Grain® had significant advantages in the base case due to lower investment costs. The situation changes, if a preservation of 400 t/a grain is considered (Fig.14). The costs of all alternatives

are now similar, because the specific investment costs of the drying and silo alternatives decrease at a greater rate than those of the propionic acid-based alternatives. However, grain preservation with Luprosil® and Lupro-Grain® remains the most eco-efficient method.



> Conclusions

Luprosil®, Lupro-Grain®

The chemical treatment of feed grain with Luprosil® or Lupro-Grain® was much more eco-efficient than the competing methods. This indicates a clear ecological and economic advantage. The two acid products show only slight differences. The advantage of Luprosil® and Lupro-Grain® over the other preservation methods would be even more pronounced if the positive effects on feed conversion ratio were taken into account.

Airtight storage

The airtight storage of feed grain has a marginally greater ecological impact than chemical treatment, but the necessary investment in an airtight silo increases costs and ties up capital for a long period of time.

Batch drying

The costs associated with batch drying are competitive with grain treatment using Lupro-Grain® or Luprosil®, but the ecological assessment is less favourable. Both drying methods are negatively influenced by their high fuel consumption and relatively high grain losses. The use of gas instead of heating oil only slightly improves the eco-efficiency of drying, and the use of electricity for drying increases the ecological impact.

Continuous-flow drying

Continuous-flow drying has proven to be the least favourable alternative for feed grain preservation. This method results in the highest costs and has severe ecological disadvantages, resulting in low eco-efficiency. The costs of continuous-flow drying decrease if a higher annual preservation capacity of 400 tonnes is assumed, but this method remains to be the worst alternative.



Fine Chemicals



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Fine Chemicals

With vitamins, carotenoids, enzymes, and other products like caffeine or the amino acid lysine, we are the leading producer of additives for both the food and feed industries. We provide a valuable contribution to healthy nutrition and ecologically efficient livestock production. Active ingredients, a complete UV filter assortment, aroma chemicals and functional polymers make us partners for the pharmaceutical, cosmetic, perfumery and aroma industries.

A reliable alliance with our customers is based on innovative products, consistent quality management and technologically leading production systems. We are utilizing our expertise in all important applied technologies and in the formulation of additives and active materials for the further development of our product range. Our customers can obtain a large proportion of their requirements for strategic raw materials from a single source.

Animal Nutrition

For animal nutrition we offer the feed and livestock production industry one of the widest assortments of feed additives, preservation and ensiling products, worldwide. Through premix plants in around 25 countries we are in the position to prepare individual mixes ready for use on each customer's demand.

Our products are applied in the manufacturing of efficient feedstuffs for the production of meat, eggs, milk, fish, or for pet food. The focus of our activities remains in the production of reliable and efficacious products. Therefore, we use our own research facilities to develop and improve our products and formulations. In this way, we support customers using our products in the optimisation of their feed formulas; and finally, we contribute to economically efficient animal production.