

GMP+ Feed Safety Assurance scheme

Study into drying processes for animal feed materials and HACCP

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1 Introduction

1.1 General

The GMP+ Feed Safety Assurance scheme (GMP+ FSA) has been developed since 1992. It was managed from 1992 up until 2009 by the Product Board Animal Feed, The Hague, The Netherlands. Since 2010, this scheme is managed by GMP+ International.

It is a certification scheme for assuring feed safety in all the links in the feed chain. It is also an international scheme, applicable worldwide.

The establishment and development of the scheme was primarily the result of demand from the subsequent links in the animal production chain for better control of feed safety. Another contributory factor was the damage caused by more and less serious contamination incidents.

In the initial phase the demand arose for better differentiation in an increasingly saturated European sales market for animal products. Since 1999, feed & food safety has been a top issue internationally both politically and commercially, because of serious incidents in the feed sector. Because of this, demonstrable assurance of feed safety has become a license to sale.

The basic principle of the GMP+ FSA scheme is that the feed chain is part of the food production chain. Proper assurance of feed safety worldwide is a high priority. Companies must live up to their responsibilities and respond properly and convincingly to the needs of food production chain. The GMP+ Feed Safety Assurance scheme is an aid to realise this.

1.2 Structure of the GMP+ Feed Safety Assurance scheme

The documents within the GMP+ FSA scheme are subdivided into a number of series. A description follows of these:

A General (framework) documents	These documents contain the requirements for participation in the certification scheme for companies and certification bodies (framework regulation, the use of logo's, etc.). This series also includes a general list of definitions and abbreviations.
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B
Normative documents.

These documents contain the international standards and additional country notes for use by companies with respect to the various feed products and production phases including cultivation and industrial production, treatment and processing, collection, trade, means of transport, storage and transshipment.

C
Certification requirements

These documents contain the Rules of Certification including those for the approval of certification bodies and auditors, the frequency of audits, minimum audit time, assessment criteria, checklists, etc. There is also an explanation of how the supervision by certification bodies is implemented and of how GMP+ International supervises the certification process.

D
Interpretations and
accompanying texts

In addition to the above-mentioned normative documents, there are also supporting documents in the D series including a list of frequently-asked questions, manuals and guidances with additional information.

Document	Code	Name
	GMP+ Dx.x	GMP+ D4.4 Study into drying processes for animal feed materials and HACCP

All these documents are available through the website of GMP+ International (www.gmpplus.org).

The document in the present case is referred to as standard GMP+ D4.4 *Study into drying processes for animal feed materials and HACCP* and is part of the GMP+ FSA scheme. It is not a normative document, but a project in cooperation with the Product Board Animal Feed . In the document you can find the original texts of the report. The information of this project can be used as a guidance for the implementation of the GMP+ FSA norms.

2 Preface

One of the actions ensuing from the Plan of Action Reinforcement quality assurance animal feed sector 1999 was preparing an insight into the risks of drying processes regarding direct drying. In particular the dioxin contamination found in Brazilian citrus pulp, as well as the subsequent dioxin contamination found in German bread flour were caused by the drying process. In addition to the fuels used, the settings of the drying installation play an important role.

It took extensive efforts to successfully complete the required inventory and risk assessment. Finally, the study was successfully completed by CCL Research in Veghel. The results have been included in this publication. This concerns a unique quantity of information, as data have not been collected on a similar scale before. However, all desired knowledge is not yet available and supplementary research is required for validation purposes.

This report contains the results of a survey into the hazards and risks involved in drying feed additives (animal feed materials) involving direct contact with hot incineration gases, in some cases mixed with tertiary drying air.

This survey was intended to result in an insight into the scope and nature of this risk in order to determine effective control measures. In addition to a report, a HACCP calculation model for 'direct drying' of animal feed materials has resulted from the project.

This calculation model seems a practical and straightforward tool to conduct a systematic *preliminary* analysis of direct drying in a wide range of situations that may occur. Validation of the model was possible only on a limited scale due to a lack of suitable data sets. The validations conducted provided a realistic risk assessment for these situations. However, the underlying data set is not, as yet, sufficient as a basis of reliable risk assessments for the full diversity of animal feed material used. Further development of this model is recommended. Conclusions based on analysis using this calculation model are always inferior to a full HACCP analysis conducted by an expert auditor.

In spite of these limitations, this provides a useful tool that can be applied in practical situations for further optimisation of risk assessment in animal feed production.

Project report – Phase 1 + 2 + calculation model
Version 1 English final



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ing".

Phase 1: Assessment and evaluation of the risks of "direct dry-

Phase 2: Evaluation of specific risks related to feeding stuffs.

With calculation model: Risk evaluation "direct drying" of feed ingredients.

3 Summary and conclusions

This report contains the results of a study into the hazards and risks of drying feeding stuffs (animal feed ingredients) involving direct contact with hot incineration gases, in some cases with tertiary drying air. This so-called "direct drying" is now only applied on a limited basis for drying food for human consumption, but is still used frequently for drying animal feeding stuffs (animal feed ingredients). This drying technique is applied in The Netherlands and in other European countries. But also especially in non-European countries, where feeding stuffs are produced and processed, which are offered and applied in animal feed in The Netherlands.

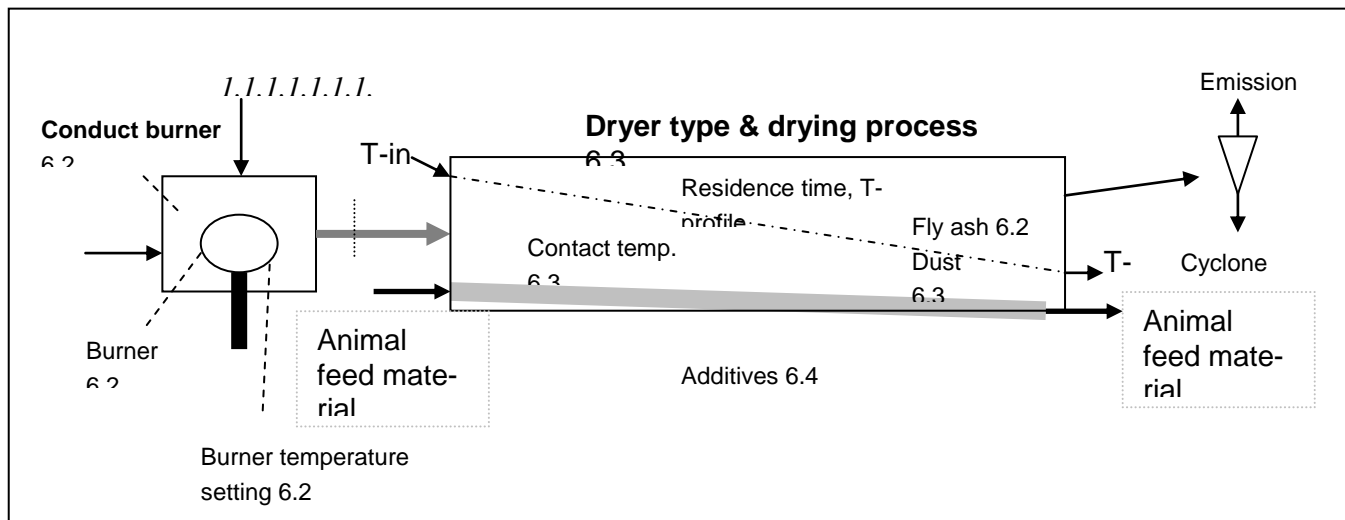
Drying feeding stuffs by means of "direct drying" has been considered a critical process step from the point of view of food safety in the "Plan of action Reinforcement quality assurance animal feed sector" of the Product Board Animal Feed (1999). Since 1999 research has been done by order of the Product Board Animal Feed (PDV) with the intention of providing insight into the nature and extent of this risk insofar as effective control measures can be determined.

The purpose of the present survey, done by CCL Research in Veghel, on request of the Product Board Animal Feed, is to provide a complete assessment and advice. This assessment and advice will be formulated on the basis of information gathered already in previous projects, supplemented with additional information gathered within this project.

The project is executed in two phases, in accordance with the agreement with PDV. Phase 1 was aimed at a generic inventory, assessment and evaluation of the hazards and risks of "direct drying processes" (Horizontal risk assessment). On the basis of the results, a calculation model has been drawn up for risk assessment in specific situations.

The insights acquired in phase 1 have been applied in phase 2 in order to assess the risks of "direct drying" more specifically for different flows of feeding stuffs. With this, a contribution is made to the quantification of "vertical risk assessment" of feeding stuffs which undergo drying processes.

The research in phase 1 started with an inventory of relevant information sources and actual and background information, which was considered necessary for realising the project aim (chapter 4.1). With this, it was again established that insufficient and only fragmentary information could be acquired through the usual sources regarding the execution and risk assessment of drying processes for feeding stuffs. Subsequently, we had to use information from other sectors (energy, waste and environment) and of personal communications of experts. Various assumptions had to be made during the research, not all of which could be verified. The acquired information is arranged by means of a diagram of the "direct drying process" (see chapter 6.2.6).



In phase 1 of this study we have tried to identify the most important “Risk Drivers” and to assess these as quantitatively as possible. We have identified the following “Risk Drivers” as being the most important of the drying process:

- fuel;
- burner type;
- burning conditions;
- temperature profile in the dryer.

Furthermore, various factors have been identified, which have an effect on the level of risk and the possibility to be able to assess this carefully enough.

The addition and mixing of feed stuffs and dust fractions can result in a (serious) additional risk.

The HACCP system assigns numeric values 1 to 4 to risks and links control measures to these values. In order to be able to assess the risks of “direct drying” well, given the multifactorial nature of the drying process, an interactive calculation model has been drawn up in which risks can be quantified on a scale of 1 to 10,000 at first (chapter 8). However, in the end this assessment will be reduced to the common HACCP evaluation scale 1 to 4. The systematic identification and (obligatory) assignment of risk assessments to hazards also results in a cause-related determination of points of interest and control measures. The calculation model makes the risk assessment transparent, also for users who are not experts in drying processes.

The hazards and risks related to fuel are dealt with in chapter 6.1.

A conclusion of this study is that “direct drying” is very well possible (without unacceptable risks) when “acceptable fuel” (natural gas, butane / propane and light fuel oil), mentioned in the PDV guideline “GMP and QC control measures regarding products to be dried and drying installations”, is used. Direct drying is also possible when various clean and checked gaseous and solid bio fuels and good quality coal are used. However, only under the conditions that these fuels are “dry” and uncontaminated and that the burning process is arranged adequately, executed in the correct way and checked systematically.

The use of waste products (liquid [e.g. used organic solvents, waste oil] and solid [e.g. plastic, scrap wood]) as fuel almost certainly leads to serious contamination of the feeding stuffs and therefore results in an unacceptable risk.

The risks related to the burning process itself (the air heater) are dealt with in chapter 6.2 (burner types and conduct of burner).

It is tentatively concluded that the choice of the burner type (adapted to the fuel), but especially the operation of the burner / air heater determine the development of unwanted material, such as PAHs, dioxins, NOx.

It cannot be assumed that burning processes in the burners / air heaters of dryers sufficiently disintegrate harmful substances in fuels (such as PAHs, DMNA (dimethylnitrosamine), PCBs, PBBs, dioxins and other organochlorine compounds). Therefore, the burning process does not eliminate the risk of fuel contaminated with these substances. The formation of NOx from air nitrogen in case of high temperatures, which occurs in case of "optimal burning" by the way, is a special point of interest.

The risks related to the temperature course in the dryer and the contact with the product to be dried are dealt with in chapter 6.3. The risks concern a) the "de novo" synthesis (neoformation) of dioxins, condensation and deposition of contaminated substances such as metal and PAHs, b) the reaction of the product to be dried with the reactive components in the drying gas (NOx, SOx) and c) unwanted chemical decomposition of the product to be dried, which can cause the formation of unwanted substances. The general conclusion of this study is that temperature courses in dryers can be sufficiently controlled in principle. Control measures for this should be determined per situation.

Risks related to the addition of additives, drying aids and dust-fractions of dried material are dealt with in chapter 6.4. In our opinion, additives should meet the product standards for feeding stuffs as determined in GMP-14. A few calamities in the past have indicated that additives can be a serious risk. Therefore, these additives should always be mentioned in the product specification and in the vertical risk analysis of a feeding stuff. Microscopic analysis of feeding stuffs is a simple method for recognising and identifying additives, also at low levels, which cannot always be determined unequivocally with chemical analysis.

Dust fractions, which have been separated from the outlet gas flow of directly heated dryers, may be transported back into the dried product. Given the chance that especially these dust fractions contain high amounts of unwanted substances, this transportation is advised against, unless it is checked that this dust fraction meets the product standards that apply to the product in question.

In phase 2 of this study the risks of some product-specific drying processes have been further investigated and mapped. The risk model developed in Phase 1 is used for this purpose. In Phase 2 we have also tried to acquire information about drying processes as these are practised outside of Western Europe and North America. Especially of drying processes in small-scale arrangements, which are executed outside of the direct range of influence and control of certified producers and traders of feeding stuffs. In order to acquire this information, interviews have taken place with experts who could give a description from their own experience of these processes and of the hazards and risks related to it. The results of Phase 2 are dealt with in chapter 7. The acquired information is relevant, but certainly not complete.

It is not possible, and it has not appeared to be meaningful either to make complete risk assessments for all drying processes which are found or can be found in the production sequences of all feeding stuffs (animal feed material).

The reality is too diverse for this and too much determined by local situations, which are, in time, also subject to change. A judgement about that in this report could wrongly lead to imputations or to phantom securities.

The definitive risk assessment of a product-specific drying process will ultimately have to be delivered to the buyer by the supplier of the feeding stuff in question (GMP 26a and 26b). The generic vertical risk analyses per product or product group are useful guidelines regarding this, although not all drying processes are adequately described in these.

The calculation model developed in this study seems to be an excellent tool in analysing and (semi-)quantitatively evaluating the risks of specific drying processes. The calculation model can be further refined in the future.

The conclusions and recommendations of this study are mentioned step by step in chapter 10 of this report. Phase 2 did not result in significant adjustment of the temporary conclusions which were drawn after finishing Phase 1.

In Phase 2 it was not proven that arranging feeding stuffs into groups related to the origin or chemical composition results in substantial additional information about the risks to be expected.

The final conclusion of this study is that drying processes involving "direct drying" can be executed without unacceptable risks for animal feed production in The Netherlands and for the food chain, provided that a number of well-defined conditions are met.

These conditions regard the "Risk Drivers" identified in this study and the application of a GMP-HACCP system to the drying processes and the flow of material that are related to those (fuels, additives, product logistics). If sufficient information about drying processes in a production sequence of feeding stuffs is lacking, the highest risk score "4" should automatically be assigned (according to the HACCP system). This means rejection of the feed additive in question, unless the safety of the feed additive in question can be sufficiently guaranteed by taking additional control measures.

In our opinion, the differentiation can be made that inadequate information about combining product flows in the "collectors" course in countries of origin can be accepted, provided that there are no indications that systematically risky methods are being used.

4 Introduction and social framework

4.1 Introduction

The study into the risks of drying processes for the safety of animal feeding stuffs, which is described in this report, has been done for the Product Board Animal Feed (PDV). It is a continuation of a number of previous studies dealing with the same issue, which have been initiated by the Product Board Animal Feed (PDV) since 1999. This study should lead to complementing previous initiatives to reach a model for risk assessment for drying processes, applied in the production column of animal feeding stuffs to a system for specific control measures for these processes, which are directly applicable in HACCP models for animal feeding stuffs (GMP 26a, 26b).

The basis of this study can be traced back to June 1999. At that time the Product Board Animal Feed (PDV) started a "Plan of action reinforcement of quality assurance animal feed sector". Causes for this were, among others, a number of serious calamities in this area. Already in 1999 this systematic action resulted in the GMP regulation for the animal feed sector. In 2000 this was supplemented with an HACCP model for the animal feed sector, which was integrated with the GMP model, which resulted in the present GMP+ model (Product Board Animal Feed, 2000).

In the "Plan of Action" four problem areas were identified, which needed further investigation urgently, since these could possibly lead to serious risks for consumers of food of animal origin. One of these four risks was described as follows: "Contamination of materials during drying in direct contact with incineration gases".

In November 1999, a study was reported by a project group of RIKILT-DLO (State Institute for Quality Control of Agricultural Products), in accordance with the Product Board of animal Feed and the study group RIGRO, and in cooperation with TNO-Food (RIKILT-DLO, 1999).

This "RIGRO study" assumed a so-called "horizontal risk analysis" of the animal feed chain, which outlines the four previously observed risks, connected with separated process steps in the chain. The specific circumstances and risks related to the specific product flows have not yet been examined with regard to this (the so-called "vertical risk analysis").

In chapter 6 of the "RIGRO report" the possible hazards related to drying in direct contact with incineration gases are identified and described in short. It is established that within the EU drying of food with "directly heated dryers" hardly occurs anymore. The most important reason for this, in our opinion, is the attempt to minimise the possible formation of carcinogenic nitrosamines (N-nitrosomethylamine, especially DMNA) in food for humans. There is no sufficient insight in the extent to which "directly heated dryers" are applied for animal feed within and also outside of the EU. Although the hazards of contamination of the product with DMNA (DNMA, DMN), PAHs, dioxin, PCBs, PBBs are pointed out, the actual risks for the food chain cannot be assessed sufficiently yet and there is not enough information available in order to establish adequate control measures.

On the basis of the RIKILT-DLO study and by the order of the RIGRO working group ("Risk Inventory of Materials), an ad hoc "sub working group drying", led by TNO-MEP (Project manager and secretary Eng. J. Boot), has tried to provide further insight into the observed risks of "direct drying" and to establish actual control measures to be taken (TNO-MEP, 2000) In their report (project number 30786 of January 11th 2000) the working group describes the nature and origin of the flows of material for animal feed, a number of drying technologies used for this and the fuels which are used most with regard to this.

The working group comes to a number of conclusions with regard to (groups of) flows of materials, fuels, and burner and dryer installations. The working group also comes to the conclusion that insufficient concrete information is available in order to come to specific control measures, as contemplated, but makes the following five recommendations on the basis of their study to be able to come to concrete and adequate control measures in a future project:

1. inventory of risk-bearing fuels and materials in potentially critical countries of origin.
2. To include possible control measures in the GMP code for animal feed.
3. Purchase policy of fuels should be included into the GMP code for the purchase of fuels.
4. Purchase policy of animal feed materials fuels should be included into the GMP-code for the purchase of animal feed materials.
5. Via the purchase policy, a monitoring programme should be introduced for the purchased materials and fuels.

According to this working group, control measures should be taken in this follow-up study with regard to fuels, burning and drying processes, generic as well as per product group and in connection with the (countries of) origin of the animal feed materials in question. Moreover, it is argued that these measures be included in the GMP-code and HACCP procedures.

Mid 2000 the steering committee "Plan of Action" of PDV concludes that no sufficient concrete control measures are formulated in the report of the RIGRO / TNO-MEP working group, in order to be able to face the problems which can occur in direct drying of feeding stuffs. Mr. Eng A.J. Rottier of the Consultants & Engineers office TEBODIN is prepared to lead a "restart project" of this ad hoc Working group Drying.

The members of this working group were expert representatives of important sections in the production and supply of feeding stuffs.

The new working group started their activities in September 2000, made an inventory of the results of previous studies, at home and abroad, defined their mission, formulated a detailed project description and a plan of work, as well as a detailed concept "Questionnaire Control Measures Drying Animal Feed Products" (and possibly Food).

The working group started formulating a "Matrix for The Netherlands" and a "Matrix for abroad" of feeding stuffs which are (probably) dried through "direct drying".

Unfortunately, this working group was not able to finish the project plan they had drawn up.

In the meantime, the Product Board Animal Feed had made considerable progress in formulating the so-called "Vertical risk assessments" according to the HACCP system for about 70 feeding stuffs classified into main groups according to the European classification of materials (96/25/EG). In a large part of these vertical risk assessments, the process step "drying" occurs once or more often (Product Board Animal Feed, GMP 26b). The basis of

the risk assessments which have been used with this and the basis of the control measures mentioned with regard to this were in fact still insufficient.

The Product Board Animal Feed made preparations in 2002 and 2003 in order to further implement the vertical risk assessment regarding the GMP regulation animal feed sector, by means of establishing a "Database Risk assessment feed material" (DRV), in which generic risk assessments should be filed per product, formulated by the producers and suppliers of feeding stuffs and additives. For these risk assessments according to the HACCP system it is also necessary to be able to assess the risks of the drying processes therein correctly and to indicate the effective control measures for the different drying processes.

Therefore, the Office Quality Policy (BKB) of the Product Board Animal Feed took the initiative, in 2003, to complete the "horizontal risk analysis" of drying processes in the production and supply of feeding stuffs by means of a concluding study in which the results of the previous studies should also be incorporated.

At the request of the Product Board Animal Feed, CCL BV made a proposal, in April 2003, for such a concluding study, with the title "Study into drying processes for animal feed materials and HACCP". In July 2003 the order was given to CCL BV and the AVO working group Food & Quality (V&K) was appointed for leading this study on behalf of the PDV.

The approach, the development and the results of this study are dealt with in this report.

4.2 Social framework

The great interest for the safety of animal feeding stuffs, additives and animal feed is related to the great public interest in food safety in general and the safety of food of animal origin in particular. The outlines for the policy within the EU have been established in the document "White paper on food safety" (Commission of the European Community, 2000), in which an independent European Food Authority is presented with great authority in this area, supported and founded by scientific advice with regard to content. Food safety should be based on the knowledge of potentially harmful substances and the (biological) effects and knowledge of the origin and/or formation in the chain of production and supply of food. In the chain of production of food with animal origin, food safety is also mainly concentrated on contamination with harmful substances, of a chemical, physical or (micro) biological nature. (European Commission, 2000. Opinion of the Scientific Committee on Animal Nutrition.)

The report "Food for thought: Safety risks in animal feed chains" (Research for policy, Q-point, 2003) drawn up by the order of the House of Representatives of the States of the Netherlands has been published recently. The complexity of the animal feed chain, the volumes and the global business flows relevant to The Netherlands; the general risks which can be involved in contamination of different materials and the functioning of the control system are described in this report. In this report, no attempt has been made to quantitatively describe the risks on the basis of existing data. It contains extremely relevant background information for this study into the risks of drying processes in the production of feeding stuffs.

The animal feed sector feels it is its own responsibility to take initiatives with regard to this. The different activities and measures which arise from the "Plan of action reinforcement quality assurance animal feed sector" 1999 of the PDV are the realisation of this.

5 Aim of this study

The aim of this study is giving a systematic risk assessment and resulting proposals for control measures for drying animal feed materials with directly heated dryers. The risks related to contamination of dried products with toxic substances as a direct result of the applied drying process. The products regard animal feed materials (feeding stuffs) which can be applied in The Netherlands.

The results of this study are intended for all parties which are responsible for the quality control in the entire chain of production, supply, purchase and processing of feeding stuffs, which means: parties which execute drying processes, parties which trade dried feeding stuffs and parties which purchase these for application as feed stuff. Indeed also for policy formulating and regulatory bodies which are responsible for the animal feed sector.

6 Focal point and definition of the project

The project plan with expected results and the definition of it is described in detail in the project proposal (CCL 335.03.P.01), which was offered to the PDV on May 16th 2003 (Appendix 10).

In accordance with the recommendations of the RIGRO working group the issue of contamination of feeding stuffs by drying processes has been divided into two complementary areas of interest, and also project phases in this project, which are:

1. Assessment and evaluation of the generic risks of drying processes which are determined by fuels, burning processes and drying processes (project phase 1).
2. Assessment and evaluation of the risks of "direct drying", which are specific to certain product groups, which are determined, among other things, by the nature of the feed additive, the interactions between the drying conditions and feed additive, and the (technological & geographical) environment where the drying process takes place (project phase 2).

The project is defined as follows (in accordance with the plan):

- The central issue is direct drying using incineration gases. Indirect drying, in which case the product does not come in contact with incineration gases, is much less risky and is not included within the boundaries of this project. Sun drying has its own specific risks (among other things micro organisms and mycotoxins) but is not included in this project either. Sun drying (drying with direct sunlight) is mainly applied to drying freshly gathered products in order to keep the product well and to make it transportable. The drying process can take a few days and can only be controlled to a limited extent (Cornelius 1973). The possible risks of drying with air that is not heated, whether with mechanical ventilation (air drying) or not, is not examined in detail in this project either. The risks can be partly compared to those of sun drying; additional is the risk of contamination by elements in ventilation air.
- Risks to be evaluated are the presence of specific harmful substances in the dried product, as far as these can be connected with executed drying processes. The risks are being assessed on the basis of accepted standards for maximum acceptable levels (action limit, rejection limit).
- Contaminations by means of the transfer from flue gases or deposit from fly ash, and which are formed in the product as a result of the drying process are discussed. Contamination that was already present before the drying process (with the same contaminating substances) can be a risk, but this is part of a different risk evaluation. Contamination as a result of the addition of additives to the feed stuffs to be dried (as part of the drying process) is considered part of this project.
- The transfer of harmful material to the product to be dried as a result of the drying process is being examined. Not the emission of harmful material to the environment as a result of the drying processes (although much information is available on that subject).
- Harmful materials that are evaluated in this project are the already identified risk-bearing contaminants which can be present in incineration gases: PCBs, PBBs, Dioxins, PAHs, SO_x, fluorine, heavy metals (especially cadmium, lead, mercury and arse-

nic). Moreover, NO_x, as a factor in the production of nitrosamines (among others) and conversions in the product to be dried as a result of over heating (caramel, Maillard products, LAL) also play a part. Through public MER data for flue gas emissions any other contaminating substances, originating from burning processes, can be identified (e.g. radioactivity in flue gases).

- The HACCP Manual Animal Feed Sector, April 2003, has been used as the basis for the risk assessment. The limit values for harmful substances published by PDV as part of GMP have been adopted as such in this study (PDV Product standards GMP - GMP-14; 09-22-2003). The standards mentioned are considered a given in the risk analysis in this report.
- In the specific risk assessment per type of feed stuff (project phase 2) only products are inspected which have (possibly) undergone one or more direct drying steps and which are offered, used, or which can be used as feed stuff (animal feed material) in The Netherlands. Feeding stuffs which are produced in The Netherlands, but are only used for export are also part of this study. The starting point for this product specific assessment in project phase 2 is the so-called "vertical risk assessments assessment" of about 70 dry materials which the PDV has available by now (Publications PDV 2000-2003, GMP 26a and 26b, DRV).

The activity "Drawing up HACCP model" concerned formulating a theoretical data work model in which information gathered during the project could be classified and evaluated, as well as formulating the in the project plan proposed operational "Calculation model" for semi quantitative risk assessment and linking that to specific control measures.

This model is further described in Chapter 8 and is also part of the results of this study which are to be delivered to the client. This calculation model is available as Excel programme for a first systematic risk assessment of drying processes (Appendix 15).

7 Execution of the study – Phase 1

7.1 Study into data and relevant background knowledge

The following sources have been referred to:

Reports, scientific literature and digital information

- The reports of the previous studies by RIKILT, TNO-MEP and TEBODIN, the relevant regulations and directions of the Product Board Animal Feed, issued as part of the implementation of the "Plan of action reinforcement quality assurance animal feed sector" and general publications about this subject.
- International databases for scientific literature, on the basis of in advance formulated search profiles, and with the help of a documentalist of WUR, an expert in the field of harmful substances and toxicology. For the toxin classes [dioxins, PAHs, heavy metals, Pb, Hg] we have searched with the search terms [drying/ combustion,] combined with [contamination, animal feed, feed stuffs]. Furthermore, the toxin classes have also been combined with [grains, cereal, barley, wheat, copra]. With these search terms we have searched in TOXLINE, Zoological Record, FSTA, ISI-Current Contents, MEDLINE and SciFinder Scholar.
- Internet : Additional information has been acquired through searches by means of all relevant headwords with, among others, the international search engines "Google" and "Altavista".

Research centres

Research centres have been consulted with the purpose of acquiring specialist information concerning the project aspects which belong to their specific field of knowledge. In some cases a specific "consultancy assignment" has been given in order to have the correct desired information gathered and offer structured information for the benefit of this study.

Consultancy assignments (on payment from the project budget) have been given to:

- KEMA, for the field of fuels, burning processes, efficiency and emissions, especially of burning processes for the (large-scale) generation of electricity. We have also spoken with Mr. B.H. te Winkel and Mrs. S. Stokman. The application of fossil and bio fuels and formation and emission of dioxins, PAHs and NOx under a number of conditions have been discussed. KEMA has also supplied data: levels of heavy metals in fuels, the degree of capture of dioxins in case of flue gas purification. The output was a report (KEMA 2003) with these data. As a result of the discussion, the remaining questions have been answered in an additional report (KEMA 2003a). KEMA did not have any specific information on dryers (appendix 13).
- NIZO, for specific information on, for the study relevant, aspects of drying dairy products. We have spoken with Mr. eng. R. Verdurmen. The conclusions of the conversation were mainly qualitative. These have been recorded in a report author-

ised by NIZO and have been incorporated as a “personal statement” (appendix 14).

- RIKILT, to test the set-up and the effect of the semi-quantitative risk model developed by CCL, and to test the assumptions made with regard to that model. During a meeting, the practical operation of the risk model was demonstrated to the researchers of the RIKILT (Mr. Dr. eng. J. van Klaveren, Mr. Dr. eng. L. Hoogenboom and Mrs. eng. M. Noordam); after that, the structure of this model and the now available data set of observed contaminations in directly dried feeding stuffs have been discussed with them (appendix 7).

The conclusion was that there is very little public information on actually found levels, while this information is essential to be able to test the hypotheses made in the model. Therefore, RIKILT has delivered a set of relevant analysis results, for the benefit of this study, from the non-public database “National monitoring animal feed RVV/RIKILT” (appendix 7).

- TNO-MEP (Environment Energy and Process Innovation), Mr. J. Boot and Mr. eng. H.C. van Deventer, experts on drying processes at TNO-MEP and chairman of the “Dutch Working Group Drying”. This renowned working group of drying experts from research and business has a good overview of all internationally available information with regard to drying processes. We refer to the internet site of the NWGD (Dutch Working Group Drying), in collaboration with NOVEM (Netherlands Agency for Energy and the Environment). This contact has only resulted in general background information on drying processes (see: <http://www.drogen.nl>).
- RIVM/CRS / Chemical Substances Bureau. Only referring to website <http://arch.rivm.nl> and to the Ministry of Housing, Spatial Planning and the Environment, Directorate Materials, Waste products, Radiation.
- Ministry of Housing Spatial Planning and the Environment, Environment DG, Direct Dusts, Waste Products, Radiation. Advice by telephone by Mr. K. den Herder concerning the standards for fuels and burning waste. We have referred to the regulations with regard to the National Waste Management Plan (LAP) 2002-2006 and accompanying sector plans and the decree BOH-13 concerning Organic Halogen in Fuels. We have also referred to the highly comprehensive website of the ministry <http://www.vrom.nl>

Companies and laboratories

Private companies and laboratories are concerned here, which are active in drying, purchasing, trading and/or analysing feeding stuffs. The information gathered has partly been acquired from discussions with qualified contact persons by means of in advance formulated questionnaires, and partly in the form of information sent at request, such as analysis data of directly dried products. The provided information is still confidential at this moment and can therefore not be added to this report

Relevant information was acquired from the following companies/sectors:

- Maasweide Laboratory Services (Nutreco), especially concerning contamination of dried feeding stuffs by polluted additives, which are used as drying aids. Maasweide has, among others, specific expertise (microscopic techniques, image processing

and reference preparations) for demonstrating and identifying additions to feeding stuffs on a level of a few percent. This discussion was held with Mr. eng. A. Swinkels and J. Zegers.

- Cehave-Landbouw Belang, Quality Control; general information on the purchase of dried feeding stuffs and the procedures for producer auditing and QC of sets of feeding stuffs to be purchased. Talked to Mr. eng. C. Gloudemans. Information concerning specifications of pit coal which is used for direct drying of lucerne and grass. Provided by suppliers as part of GMP+.
- Robi Droge Diervoeders B.V. and P.C. van Tuijl Kesteren BV.; written information, sent by Mr. Eng. A. Gotink on his own initiative, regarding his own study of levels of dioxins and PAHs in drying bread. Levels before and after the drying process were compared. From these levels appeared that no demonstrable deposition of PAHs and dioxins occurred. The examined samples amply met the applicable quality requirements for dioxins (0.75 ng WHO-TEQ/kg product) and PAHs (1 µg/kg BaP/kg product) in animal feed.
- IRS-dep. Animal feed. Written information regarding dioxins/PCB in treacle and dried beet pulp (in pellet-form) measured externally by the order of a number of beet pulp producers, led by the IRS, during the campaigns of 2001, 2002 and 2003. Information sent by Mrs. Eng. M. Kaemmerer van Os. The dioxin levels which were found in this study are very low and amply below the EU standards (0.75 ng WHO-TEQ/kg product and 12% humidity), as well as the accepted action limits (0.5 ng WHO-TEQ/kg product and 12% humidity). PCB levels are also extremely low. The report will be published by IRS in due time.
- ADM Europoort; Question with regard to drying soy by-products among other things. In a telephone conversation with Mr. J. Spek it became clear that ADM switches over, and/or has already switched over, from direct drying with gas-heated installations to drying by means of indirect heating.
- NVG-Nederlandse Vereniging van Groenvoerdrogers (Netherlands Organisation for Greenstuff Drying); in some telephone conversations with Mr. eng. J. Leutscher, advisor VNG, we have discussed which critical issues are present with regard to direct drying of grass and air (and among other things processed to flour and pellet) with pit coal for fuel. The QC/QA measures and control measures applied by NVG members have then been summarised in writing and sent. NVG members work according to a detailed quality manual. The coals used are from a known origin and specification, in which case transport and delivery are monitored; the drying process is set, followed and data are being recorded; as part of GMP, sample research is done, among others by RIKILT.
The remark is made that dioxins and PAHs can be present in these products by contamination of the crops on the field. The increase as a result of the drying process can be disregarded. Information has been given on studies in Denmark, France and The Netherlands with comparable results.
- N.Z.O. Nederlandse Zuivel Organisatie (Netherlands dairy Organisation); Conversation by telephone with Mr. eng. P. Mathot. For an important part, an abstract and actualisation of his contribution in the RIGRO working group. Confirmation of the ex-

tremely well secured situation in the Dutch dairy industry, also with regard to products intended for animal feed, such as skimmed milk powder and whey powder products.

Attention was specifically asked for the risk of unintentional pollution of fuels (especially liquid) since HACCP has a very different character in the fuels sector than in the food and animal feed sector.

- Suiker Unie; Telephone conversation with Mr. eng. J. Dijkstra for information on the fuels used for drying sugar beet pulp, the implemented controls in the purchase of fuel and the arrival of it, and the type of dryers used. In The Netherlands, the sugar industry uses natural gas or light fuel oil, which is purchased on high specifications, related to the requirements for (direct) drying of beet pulp and the environmental requirements for the emissions of the pulp drying houses.

The supplied sets are also analysed for specifications and pollution before use.

- NOVE; *Nederlandse Organisatie Voor de energiebranche (Netherlands Organisation for the Energy Sector)*. Conversation by telephone with Mr. W. Schouten about specifications of liquid mineral fuels and maximum permitted levels of unwanted substances. All operations of the NOVE members are ISO 9002 certified. We have been provided with useful oral and written information with reference to the NOVE website: www.nove.nl
- Shell Nederland Verkoopmaatschappij bv, Capelle a.d. IJssel; Request for information on PCB in fuels. The sole statement that these are absent within the set standards. No concrete statement of levels.

The PDV-AVO working group Food and Quality (V&K) has commented on the different concepts of this report orally and in writing in the mid-term reports of November, December, January and April.

7.2 Evaluation and processing of literature data

7.2.1 Evaluation of the acquired information

Public literature and company data from the food and animal feed sector, as far as found in this study, mainly concern levels of harmful substances in the food or the animal feed material before and after drying. From the viewpoint of product quality assessment this is correct. The process conditions under which drying has taken place (fuel used, burner and dryer settings, composition of drying gas) are generally not described or incomplete. This way the measured variables remain "ad hoc" and are not sufficiently suitable for a systematic risk inventory. These cannot be used to predict which changes of conditions in the drying process can lead to a strong increase (or decrease) of the levels of harmful substances in drying gases and directly dried animal feed materials/feeding stuffs. It is difficult to establish whether the conclusions are objective when essential data are missing in a data set.

Such measured variables become very valuable when these can be linked to data on equipment, operational management and composition of drying gases. Then the trans-

fer factor for contaminating substances from flue gas can also be determined for the relevant feed stuff. This factor indicates the sensitivity of the relevant feed stuff to the transfer of certain unwanted substances during drying (Phase 2 phrasing of the question).

Data regarding primary emissions of furnaces of power stations and waste incineration, such as obtained from the order to KEMA, are available and valuable, but not directly useful for assessing and limiting the hazards and risks of direct drying of feeding stuffs. Facilities for flue gas purification and capturing of fuel dust (before the dryer) are probably not or hardly available for direct drying processes. They are being applied for purification of the drying gases after the dryer, for protection of the environment from the drying installation as a whole (dust & smell, emissions). Measurements in flue gas of dryers (in other words emission measurements) without any further information about process conditions do not produce knowledge about the transfer of harmful substances. However, emission control of dryers is not one of the aims of the current project, although it is of course very important from the environmental viewpoint and for the operational management of the drying industry in inhabited areas.

In order to clarify how this information on emissions is nevertheless made useful for the risk assessment of direct drying processes for feeding stuffs, a model comparison is presented in chapter 5.2.4.

7.2.2 Current knowledge gaps regarding process influences on contamination risks

- There is little public literature on the presence and transfer of harmful substances during drying processes. Literature regarding measured levels of PAHs, fluorine and heavy metals (mercury) in dried primary agricultural crops (e.g. greenstuffs and grains) practically always includes contamination as a result of deposition from the air on the crop in the field by air pollution. In many cases no distinction is made between contamination which is already present before and which occurs during the drying process. The contribution from the drying process cannot be precisely determined in that case.
- In none of the found descriptions a direct link is made between the drying process and the observed contamination. This makes it difficult to interpret this data.
- Information about formation and transfer of unwanted substances in this report practically entirely comes from studies into waste incineration and power generation, large-scale (power stations) and small-scale (wood burning installations). In the absence of other information, this information is taken as a basis for the assessment of possible formation and transfer of unwanted substances in direct drying processes.
- The observations made above implicate that a number of hypotheses had to be formulated in order to fill the risk model. This is the case for the transfer factor in particular. There is no clear information about the degree of transfer to the products to be dried, and it is not clear either whether the composition of feeding stuffs influences this.
- In many cases which have been examined and calculated until now it appears that the drying process can be controlled and the executed checks show that the levels of harmful substances do not exceed the standard.
- However, the information gathered until now is probably not representative of situations in smaller, often not industrial installations outside of Western Europe and Northern America and especially in (developing) countries where important flows of feeding stuffs come from.

The specific description of a number of these drying processes as well as an evalua-

tion of the related specific risks for the relevant feeding stuffs is therefore part of Phase 2 of this project.

7.2.3 Processing of acquired information

The process of processing the acquired information went as follows:

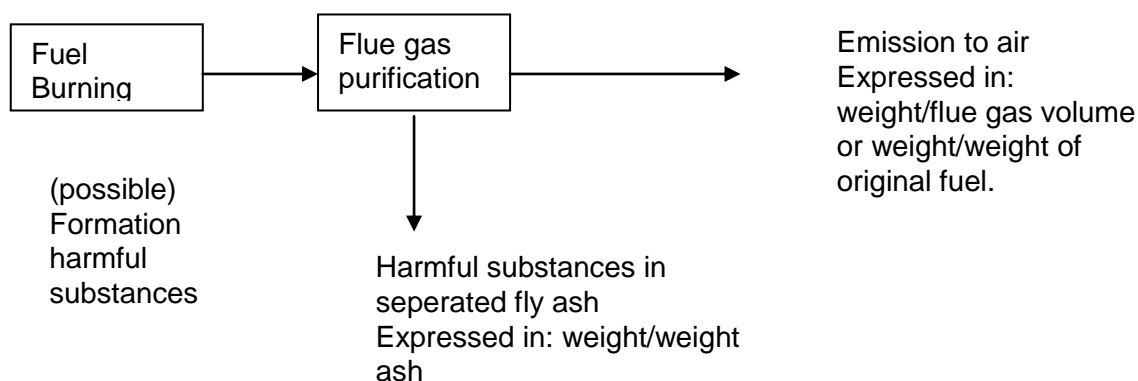
- Comparing the already available information and determining the degree of reliability, internal consistency, similarities, complementarities and incompatibility with other information, indicating gaps in the information which reduce its usefulness. Completing the information if possible.
- Testing, per examined subject, against regulations for feeding stuffs, GMP and HACCP.
- Processing the information in the relevant chapters of this report.
- Entering data in the relevant tables and calculation rules of the HACCP calculation model.
- Recording in the index of sources and bibliography.

7.2.4 Comparison of burning processes in case of power generation and direct drying, for data interpretation.

The risks in case of direct drying are to a high degree determined by burning processes as such. Similar burning processes are also frequently applied in case of power generation for electricity, heat and processing of waste. Much research has been done with regard to burning processes for power generation and processing of waste. This research is mainly aimed at energy efficiency and flue gas emissions to the environment. Data from these kinds of processes can, in principle, be used for the risk inventory for "direct drying", provided that the differences between burning processes for power generation and burning processes as part of drying processes are taken into account.

This is why both uses are compared in the diagram below

Figure 1 Burning for large-scale power generation (diagram)



Mass balance harmful substances: Formation = Out through flue gas purification + Emission

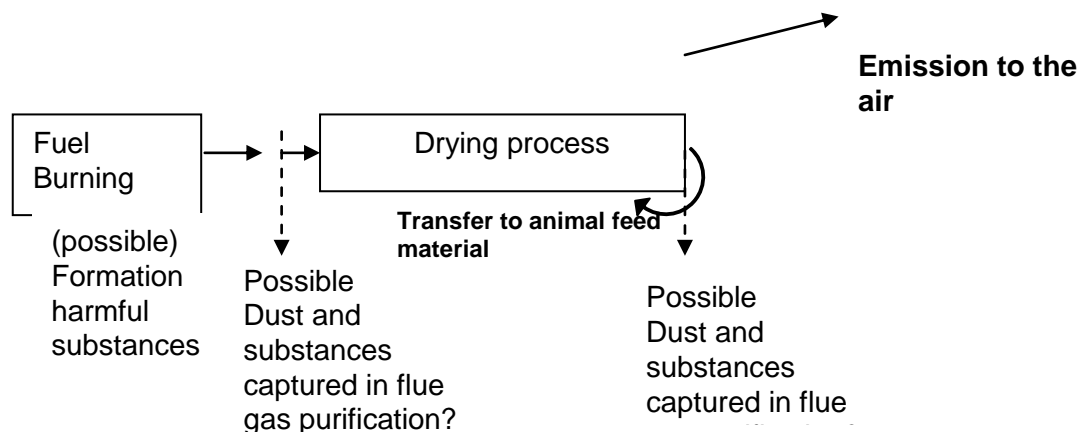
The aim of this process with regard to harmful substances is minimising emissions of harmful substances through the flue gases, by:

1. Preventing the formation during burning as much as possible.
2. Flue gas purification, aimed at removing harmful substances from the primary flue gases as completely as possible.

Measurements of harmful substances (such as KEMA does frequently) are then mainly aimed at minimisation of the emissions and to indicate this if desired.

The formation and emission of harmful substances has been discussed with KEMA. The conclusions from this consultancy have been mentioned in a note by the order of CCL Research (KEMA, 2003, H. te B.H. te Winkel, appendix 13). The data in this KEMA report are mainly derived from burning processes for power generation, heating and processing of waste. By the way, this also applies for most of the other consulted literature.

Figure 2. Burning for direct drying processes
Variants aside, these processes run as follows:



Mass balance harmful substances:

$$\text{Formation} = \text{Transfer to animal feed material} + \text{Emission to the air}$$

Flue gas purification and separate capturing of dust did not occur in the evaluated cases of direct drying and that is why they have been ignored in this study.

7.2.5 Driving forces in design and execution of drying processes.

Drying feeding stuffs, in one of more stages in the winning and/or processing process, is driven by economic motives. The purpose of drying feeding stuffs is usually to preserve these, and/or to make them non-perishable, transportable and tradable. Therefore, drying adds value to the feed additive, but also considerable costs. Sun drying and air drying are possible with relatively simple installations, without the costs of drying energy. Drying with heated air is a relatively expensive process for the producer of feeding stuffs. In many cases 25-40% costs are added on the basis of the value of the dry material. These costs can be divided into costs for the installation and costs for the operation of that installation. The fuel costs easily amount to 30-50% of the total costs.

The larger the installation and the more it has an industrial character, the greater the costs of (the investment in) the installation usually, the result of which is that the technology which is available at that time is also fixed for a longer period of time.

Many dryers of feeding stuffs were built before people were interested in deposition and the formation of harmful substances in the product. People have become interested in this mainly since the nineties. Within the available technical and commercial boundary conditions the processing has to be adapted to the new requirements. The design requirements of drying processes for feeding stuffs were usually of an entirely different nature. The following was important with regard to this:

- nature and characteristics of the material to be dried and already dried;
- volume and pattern of the availability of moist feeding stuffs;
- availability and price of fuels (energy), sometimes from parallel processes;
- availability of additives and/or other flows of products;
- emission requirement with regard to the drying process, environmental requirements with regard to discharging/dumping of wet product;
- availability of capital for investments and the willingness to invest.

The design and process requirement “preventing contamination of the product” has been added to that more and more authoritatively in the last decade.

The main purpose of this study and the resulting recommendations for control measures and conditions is: limiting the undesirable side effects of the drying process with regard to contamination of the animal feed material to be dried with harmful substances. And particularly, preventing that by controlling the process.

The operator of the drying process can minimise these undesirable effects by taking measures, during all the aspects of the drying process, which make the risk of contamination of the product as small as possible. In order to be effective, the most important risk determining factors (the so-called “Risk Drivers”) should be identified and controlled.

On the basis of the previous studies in this area and on the basis of the information which has been acquired for this project, we can conclude which are probably the principle risk determining factors (“Risk Drivers”) in case of drying processes in which the product to be dried comes in direct contact with drying gases from burning processes.

These can be arranged logically in the order in which these come up in the drying process. Usually this is also the order in which control measures should be taken with regard to the drying process.

The following are considered the most important risk determining factors (Risk Drivers”):

1. The composition of the fuel.
2. The design and execution of the incineration process.
3. Temperature time course of contact of the product with the drying gases.

Additions to the feed stuff as part of the drying process are not designated as “Risk Driver”, but these can involve a (serious) additional risk.

In chapter 6 these risk factors are discussed systematically; the possible hazards, the seriousness in case these occur, the possibility that these occur (“Risks”) as well as the measures which can (and should) be taken in order to minimise the risk and to control continuously (PVA, CCP).

These data and assessments have also been incorporated into the HACCP calculation model, which is discussed in chapter 8 and which has also been added to this report as an active EXCEL calculation model on disk (appendix 15).

The data sets in this calculation model are further completed (where possible) and further validated in Phase 2 for specific drying situations for specific feeding stuffs.

The data set of the calculation model can also be further completed after this study, on the basis of new information and advancing insight.

7.2.6 Classification of study results in the next chapter of this report

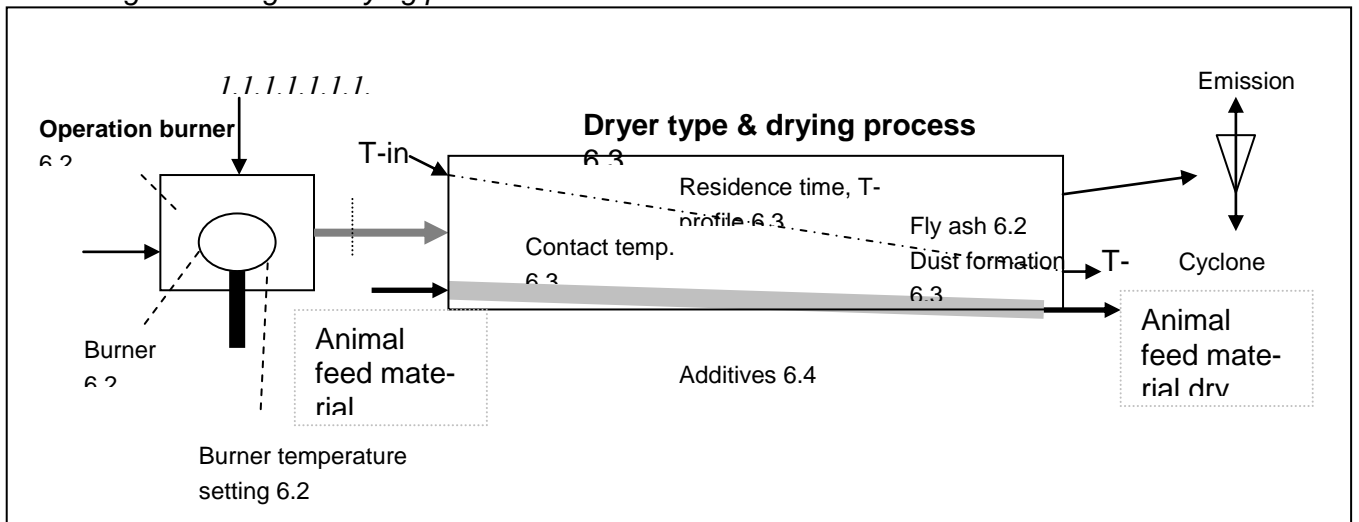
The study results have been classified as follows:

- 6.1. Fuel, types, risks, check
- 6.2. Burner type
 - Conduct of the burner
 - Setting the burner temperature
 - Completeness of incineration
 - Flue gas purification
- 6.3. Dryer type, and with that boundary conditions for conduct of dryer
 - Temperature profile in the dryer
 - Contact temperature drying gas/product to be dried
 - Formation and deposit of fly ash
 - Control dust formation
- 6.4. Use of drying additives

In the figure below (figure 3) the drying process has been represented in a diagram in which it has been indicated which aspects are discussed in which paragraph of this chapter.

Note: the air “heater/burner” is a different unit than the actual “dryer”. Different combinations of “heaters/burners” and “dryers” are possible.

Figure 3: diagram drying process



5.3.

8 Execution of the study in Phase 2

As part of project phase 2 we have spoken with a number of experts. These experts have been approached on the basis of their assumed expertise, their current or previous experience in the animal feed sector and the international industry of feed raw material. We have also spoken with producers of drying equipment by phone. The purpose of these conversations was to gain better insight into the specific risks, if present, related to drying feeding stuffs in “less controllable circumstances”, especially outside Western Europe. We have also tried to find out whether specific links can be made between the nature of the material to be dried and the risks of the drying process. The conversations were held according to a standard questionnaire, which was formulated for this purpose (appendix 9).

Detailed conversations were held with:

Eng. J.L. Váhl, in Gennep, independent advisor international projects, former Production and Technology Manager at Hendrix Voeders in Boxmeer.

Mr. J. Nicolai, purchasing manager at Hendrix-UTD Voeders in Boxmeer.

Eng. W.W.M. Spreeuwenberg, independent advisor international projects, former Feed & Quality Manager at Cehave-Landbouwbelang in Veghel.

Eng. F. van Poppel, chief Food & Quality, Cehave-Landbouwbelang Voeders in Veghel.

We have tried repeatedly to come to a conversation with some large international feed raw material suppliers.

None of these contacts resulted in an conversation concerning the content of this study, as we had in mind.

In the beginning people showed a sympathetic attitude, but ultimately the confidentiality of business processes and drying techniques used turned out to be an insurmountable barrier for an informative conversation. This reserve can be explained, among other things, by the small additive value and relatively high costs of the drying process.

Our contact persons have assured us, however, that their company has internal procedures which sufficiently guarantee the safety of drying processes and dried feeding stuffs. The contents of those have not been further explained.

We have also tried to come to an informative conversation with some international operating manufacturers of industrial dryers, among others Van Aarsen, Geelen Counterflow, Lödige, Stela-Laxhuber. None of these manufacturers turned out to be willing to give information about operating procedures of the users of their equipment.

Through additional source research some additional information has been acquired about fuels. This information has been added to chapter 6.1 “Fuels”.

Further examination of the information on NO_x in incineration gases and the related risk assessment for nitrosamines in case of direct drying of feeding stuffs, has resulted in a review of chapter 6.2.2. “Conduct burners/air heaters” and in the removal of the semi-quantitative risk assessment for NO_x from the calculation model. Arguments for this are given in appendix 12.

9 Study results of project phase 1.

9.1 Fuels

The fuel type with which the air heater (burner, heater) of a "direct dryer" is heated, highly influences the possibility of the occurrence of harmful substances in the drying process. This apart from the other factors which play a part in "direct drying". The risk for formation and transfer of harmful substances during incineration can be considered an intrinsic quality of the fuel. Fuels can be subdivided into gaseous, liquid and solid fossil fuels and "bio" fuels on the basis of composition, nature and origin. Each of those have their own risk profile.

In order to be able to evaluate the risk profiles it is necessary to describe the fuel type as unequivocal as possible. For this purpose statutory names, business specifications and the like are used, as far as these are important for the risk assessment of drying processes. The main issues are summarised in appendix 11 and are further discussed below. These data are important in making a responsible choice of fuel.

Beside the nature of the fuel, the origin (the raw-material producing area, processing) and handling (storage and transport, with the possibility of pollution) are also important for the risk assessment. An elaborate discussion of these aspects is not included in the scope of this project.

Gaseous fuels

The following gaseous fuels are available for burners/air heaters for dryers: natural gas – NG or CNG (Compressed Natural Gas), Liquid Natural Gas – LNG, Biogas (Land fill gas), Liquefied Petroleum Gas (LPG or refining gas), often supplied as purified "Butane" or "Propane". The main components of these gases are linear alkanes, which burn entirely to CO₂ and H₂O, in the right circumstances. Commercially refined "Dry Natural Gas" contains (depending on its origins) 87-96% methane and a small % of ethane, propane and butane. Moreover, also small amounts of N₂, CO₂ and H₂.

Occasionally locally available gases from the industry can be used, such as cokes gas and blast furnace gas. These gases consist of a mixture of hydrogen gas, carbon monoxide and alkanes. Furthermore, CO₂ and nitrogen occur. The non-purified gases contain PAHs, among others naphthalene, which is usually removed before use. Because the conditions for the formation of dioxins (temperature course, presence of water, chlorine and organic dust) seem favourable, the formation of these cannot be excluded. Indeed, it is indicated that dioxin formation occurs in cokes production. (Cost Curves for the abatement of heavy metal, PAHs and dioxin emissions, 2002)

Possibly with the exception of dioxin, the fuels mentioned until now do not give reason for worry with regard to the occurrence of harmful substances. The influence on the calorific values is only limited. Complete incineration can easily be realised in case of gaseous alkanes, CO and H₂, and nitrogen will not significantly contribute to the formation of NO_x in case of low levels, provided that low-NO_x burners are applied.

A correctly adjusted gas flame has an extremely high temperature (up to >1900°C) which principally causes all organic components in the gas to fully burn. However, because of the high temperature there is a greater risk for NO_x formation by oxidation of N₂ from the combustion air. In order to prevent this, various "low-NO_x burners" have been designed espe-

cially for gas (Gasunie Nederland NV; Natural Gas Composition, Union Gas; University of Houston Law Centre, Institute for Energy, Law & Enterprise; Shell Global Solutions – Analytical technology; IFRF Research Station b.v.; MSN Encarta – Natural Gas).

Non-purified “Wet Natural Gas” can contain considerable levels of higher alkanes and aromatic hydrocarbons. So-called “Sour Gas” contains considerable levels of H₂S and other sulphurous substances, which makes it toxic and which cause the intense smell. Non-purified Biogas and non-purified cokes gas, blast furnace gas and so-called pyrolysis gas (gaseous decomposition products which are produced by strong heating of organic waste products, Jorapur en Rajvanshi; 1997) can also contain these impurities. In case of incineration, mainly SO₂ is formed from sulphurous compounds. This is not acceptable from the viewpoint of emissions, but it is not considered an important risk in the viewpoint of contamination with harmful substances. Usually these gases will have been purified before distribution. Commercially supplied gases for use by private consumers (households) and in dryers should be odourless, except for the typical smell of a detection chemical, usually mercaptan. The presence of aromatics in the gas can possibly increase the risk of PAHs and/or dioxin formation in case of suboptimal incineration conditions. Therefore, the presence of such compounds should be known.

In designating gaseous fossil fuels as fuel for dryers, little distinction is usually made between the different gases in literature. “Natural gas” is usually used. Sometimes LPG is mentioned (mixture of butane/propane). Producers of LPG, propane, butane (among others Shell, BP) indicate in their product specifications that their gases for industrial purposes are dried and purified.

Cokes gas is still produced in various European and non-European countries, usually as a side product of coal extraction or iron extraction from ore. This gas is used for heating purposes and it is clearly indicated that substances such as H₂S, NH₃, tar, benzol (= lower aromatics) and naphthalene (one of the PAHs) are specifically removed (Ispat Nova Hut, www. Novahut.cz). Non-purified cokes gas can contain high levels of aromatic hydrocarbons (PAHs) and should not be used as such in burners for direct drying of feeding stuffs.

In practically all literature it is stated that gas as fuel for dryers does not lead to specific problems, or nothing is mentioned about it.

Only Tilgner (1970) states, after discussing direct drying with gases as fuels, that a direct drying process should never be used for (human) food no matter which fuel is used. A conclusion which can be entirely endorsed on the basis of the ALARA principle for the formation of nitrosamines in food under the influence of NO_x in the drying gas (also see chapter 6.2.2).

Others, when applying gaseous fuels, base themselves on the hypothesis that in using gas no increased levels of harmful substances will occur in the dried product (Rezchikov, 1983; Fritz, 1983; Poulsen, 1987; Wilkins, 1991). The last two authors do note that “low NO_x” burners are necessary to prevent the formation of NO_x. In only one case pollution of natural gas is mentioned (S-compounds, NO_x; Hg, Woggon, 1978). However, it is not clear in this case which amounts are concerned. Therefore, gaseous fuels (like all other fuels) should also be purchased on specification and with guarantees for the absence of unwanted pollutions (GMP and HACCP fuels).

Liquid fossil fuels

For liquid fossil fuels, classes are distinguished which are connected with the composition, boiling point, the burning qualities and impurities present. Examples of liquid fuels are petroleum, light fuel oil, diesel oil and heavy fuel oil.

In The Netherlands (and in most European countries) legal requirements apply for fuels to the composition and maximum levels of some unwanted substances, such as PCB, organo-chlorine compounds and Sulphur.

In The Netherlands it applies that no liquid fuel may contain more PCBs and PCTs than 0.5 mg/kg (ppm) per congener, and besides not more than 50 mg/kg (ppm) halogen hydrocarbons, calculated as chlorine. However, for aviation fuels a maximum of 500 mg/kg (ppm) applies.

A maximum sulphur level of 0.2 % w/w applies for red gas oil (HBO), 0.05% for white diesel oil (ADO) for road traffic. For fuel oil a maximum of 1.0% sulphur applies. However, heavy fuel oil can contain up to more than 4.5% sulphur. Buyers often also make requirements with regard to the ash level and the level of heavy metals, including Ni, Cd, As, Hg, Pb and V (see appendix 3, KEMA, 2003). The standards in the different EU countries are not uniform yet (NOVE). The regulations are highly complex.

Liquid fuels are usually delivered with specification with regard to the composition per delivered lot. Lubricating oil, engine oil and hydraulic oil are not intended as fuel. Not as such and not as "waste oil". These can contain additives (sometimes even considerable fractions) of substances which, in case of incineration, create a considerable hazard for contamination of products to be dried (among others PCB and metals).

The consulted literature mainly consists of reports in which the contribution of the incineration of various types of oil are linked to environmental pollution. Furthermore it consists of articles in which, in discussing a drying process, the conditions, such as fuel type, are also briefly mentioned. Hardly ever are the differences in fuel compositions explicitly explained. Recycling oils (used oil etc.) are often mixtures of unknown origin and with an unknown composition. Deliberate mixing with combustible chemical residues has been recorded regularly in the past (including the TCR affair). Assessing the possibility of harmful substances in the drying gas is therefore not possible for these unspecified "fuels". In case of incineration of an undefined liquid fuel the level of contamination can be low, but also unexpectedly high (KEMA, 2003; RIVM-TNO, 1993; EPA 2002). This also applies to additives of these products, such as anti-dust oil to coal, cokes or other solid fuels. During interviews with some experts the risk was pointed to that particularly liquid fuels can easily and unintentionally be polluted with other organic flows during transport and storage, as a result of which the initial specification is no longer applicable at delivery.

Liquid fuels are also a typical risk for pollution with PCBs and PBBs. PCBs do not naturally occur in refined liquid fuels. Shell Nederland even guarantees (by telephone) that there are no PCBs present in their diesel oil and fuel oil. This could be considered "below the detection limit". The generally applied analysis method has a limit of detection of approx 5 µg/kg (5 ppb) for total PCBs. That would mean a factor 100 under the NL standard for fuels. Used oil is considered a "hazardous waste product" according to the EU directions with regard to Management of waste products (European Union: 75/439/EEG, 75/442/EEG, 87/101/EG, 91/689/EEG, 94/67/EG). At the same time attempts are being made to make the reuse of "highly calorific waste" as fuels possible, for instance in electricity generation,

cement production and blast furnaces. In The Netherlands it has been recorded in the National Waste Management Plan (LAP) 2002-2006, sector plan 23 "oil-bearing waste" and Sector plan 24 "PCB-bearing waste" (VROM, Environmental Management Act) that waste oil with a PCB level of >0.5 mg/kg (0.5 ppm) per congener will be assigned to Category IV (waste for which a licence is needed in order to dispose of it). Waste oil with an Organic Halogen level of >1000 mg/kg (1000 ppm) will be assigned to Category III. Neither of these should be mixed with other fuels and can only be disposed of in a controlled way (<http://www.wetten.nl>)

The Basel Convention; PCB, PCT and PBB technical guidelines, (2002) indicate that liquids with a total PCB level of at least 50 ppm (mg/kg) should be considered "hazardous waste", while it is recommended for bulk products with levels of 2 - 50 ppm to put these under strict supervision (also see OECD classification).

The Central Pollution Control Board (Delhi) defines oil as "waste oil" with the classification "Hazardous waste" (CPCB 1989, 1998) if the following is found in it: > 5 mg/l total PCB/PCT/PBB and/or > 100 mg/l "chlorinated solvents, benzene and total PAHs and/or > 100 mg/l of each of the heavy metals As, Ba, Cr, Cu, Cd, Ni, Pb, Zn.

According to the Basel Convention, such products should be offered to controlled disposal and should definitely not be sold or used as fuel.

The UNEP Chemicals Survey (August 2000) (Helsinki Commission PCB's 2001) prescribes that highly specific burning conditions are necessary for the disposal of PCBs, PCTs and PBBs (>1200°C, 2-5 sec., 6% surplus oxygen, high turbulence), which are not realised in the standard burners (800-1000°C). Burning in these conditions costs USD 1000-3000 / ton and is therefore definitely not an economic incineration process for industrial use.

The accuracy of these conditions for disposal has been recently confirmed in scientific pilot studies, among others by G. Söderström (2003) Since many "rearrangement reactions" occur during the burning of PCBs and PBBs, a wide range of poly-chlorinated (brominated) aromatics can be produced from those which should be considered as POPs (Persistent Organic Pollutants) and which are in part highly toxic. Although PCBs and PBBs are no longer produced in Europe and Northern America, there are still large amounts of these in circulation all over the world and the formal aim for world-wide elimination is set to 2028 (Basel Convention 2002). The presence of PCBs and PBBs in uncertified fuels will still be a realistic hazard in the coming decades, also because of the high costs of controlled disposal. Given the high persistence and high transfer efficiency and the possibility of dioxin formation in the burner, fuels with a demonstrable level of PCBs, PCTs and PBBs are unacceptable. This also applies to fuels with demonstrable levels of dioxin and POPs. Therefore it is necessary to request a certificate with each delivery of liquid fuels and to regularly determine the accuracy of it by means of self-checking. It is advisable to include in it that the fuel does not contain components from (oil) recycling.

Solid fossil fuels

These include pit coal, cokes and brown coal in various quality classes.

The fuel business uses the following definitions:

Designation	Carbon %	Other features	Energy
Brown coal	<60%	Incompletely mineralized	2,8 kWh / kg
Lignite	60-70%	Water, ash, hydrocarbon	7 kWh / kg
Butiminous coal	75-91.5%	Hydrocarbon 7-20%	9 kWh / kg

Anthracite	> 91.5 %	Purified pit coal	> 9 kWh / kg
Cokes	-	Degassed pit coal	8 kWh / kg

(origin: Steinkohle Portal, <http://steinkohle-portal.de> and Oscar van Vlijmen, May 2000)

A slightly different classification, based on applications, is the one in Thermal coal, Metallurgical Coal, Anthracite, Petcoke and coal products for household use, including briquets. Petcoke is a distillery residue from petroleum refining. It cannot be used as fuel for direct heated dryers (Source: SSM Coal; <http://ssmcoal.com>).

Solid fossil fuels in the same category, but from different origin, can differ considerably in terms of composition (KEMA, 2003; Merrill, 1985). Beside carbon, brown coal and pit coal also contain varying levels of silicium & salts (ash), bituminous material (PAHs), sulphur, halogens and heavy metals. It is therefore necessary to request a detailed product specification with mention of the origin for each delivery. These are available in the bona fide pit coal business. An example of such a product specification of a pit coal which has been found suitable for direct drying of grass and lucerne, has been included in appendix 5.

It should not be ignored that solid fossil fuels can contain a small amount of radioactivity. The radioactivity comes from the heavy metals uranium and thorium, which can sometimes be found in pit coals in varying levels just like other heavy metals. It is also supposed that these metals almost entirely end up in the coal ash. The level for U varies from 1-10 mg/kg, depending on the working excavation. For Th these values are approx 2.5 times as high. The American EPA adheres to the average values of 1.3 mg/kg U and 3.2 mg/kg Th. Not only these elements, but also for their decay products radium, radon, polonium, bismuth and mercury (Gabbard, www.ornl.gov). In the usual specifications no attention is paid to this. It is not clear to us whether this should be considered a hazard. For now, radioactivity is not included in the risk assessment for solid fossil fuels.

During mining, storage and in the long logistic chain until the end user, solid fuels can also be polluted with persistent substances which, when dried, can cause contamination of the feed additive to be dried. A known hazard is applying "waste oil" as anti-dust product in the transfer of coal and cokes. In case of burning fossil fuels the burning conditions in combination with the actual composition of the fuel will most certainly determine the emission of PAHs and other substances in the flue gases and also the formation of dioxins. After all, in the right burner conditions and in case of a sufficiently high temperature, the organic component in each fossil fuel can be entirely converted into CO₂ en H₂O. The Si and mineral, nitrogen, halogen and sulphur compounds will partly evaporate, and partly remain behind in the ashes. It is important to establish which part of this can end up at the product to be dried (as fly ash). However, because of the nature of the solid fuel, complete burning (without residue) of the organic substance is less easy to realise than in case of gaseous or liquid fuels. Heavy metals are present in the fuel by nature. In case of fossil fuels, particularly coal, depending on the origin, can contain various and sometimes relatively large amounts of metals. We refer to appendix 4, table 2 for an overview.

In order to minimise the formation of NO_x one concentrates on (as discussed in gaseous and liquid fuels) minimising the oxidation of the air nitrogen by controlling the burning conditions. Particularly in case of coal, however, NO_x can also be formed from nitrogen compounds which are present in the fuel. Solid fossil fuels should always be purchased on specification and with a certificate. That makes control of the amounts of contaminating

substances in use of fuels in direct dryers possible. Renowned suppliers operate with ISO quality systems, which guarantees the composition and origin and the entire logistic course.

Bio fuels

Non-fossil products from animal or vegetable origin, for the sake of convenience summarised to "Bio fuels", are applied "single" and also as an additional fuel to fossil fuels. From the overview which has been made by KEMA by the order of CCL Research (KEMA, 2003) it appears that there is a wide range of bio fuels, such as straw, (clean) wood chips, coconut shells and cacao shells, bagasse. In some areas (for example Brasil) "wood for heating" is cultivated on a large scale and applied in the agribusiness. These types of fuel can be characterised as vegetable/fibre-like/wood-like with regard to structure and composition. If these fuels are clean and dry, the risk is relatively low. From the literature consulted it can be concluded that no great differences are found regarding the formation of harmful substances. It can be noted that with regard to NO_x formation, the use of these types of fuels results in a relatively low formation. Using it as supplementary heating product can even reduce NO_x formation: a rule of thumb is that 1% additional heating with bio fuels results in a 1% reduction of NO_x formation (KEMA 2003). Therefore, it does not seem useful to consider clean unprocessed wood and clean dry wood products separately without further additions.

These have no special risks if the origin and composition can be guaranteed.

This is different in case of processed and recycled products. These include for example preserved wood and scrap wood and also vegetable materials which have been processed with preservatives, insecticides or which have been contaminated with oil or chemicals (e.g. sawdust). Important harmful substances in this case are mainly PCBs, organochlorine products, metals and metal salts. Moist bio fuels increase the possibility of "de novo" synthesis of dioxins and PAHs, because the burning temperatures may remain in the critical range of 200-600°C (KEMA 2003, Söderström 2003). In appendices 1 (dioxins), 2 (PAHs) and 3 (heavy metals) this is discussed further.

Bio fuels of a different composition and origin, which are produced as a by-product of local agri-industrial processing processes should be evaluated separately. Data regarding this are usually fragmented. Dry citrus peelings should for example be suitable as fuel (company info "Vincent Corporation", 1988). On occurrence of dioxins it is only mentioned that with correct processing, the amounts meet the American standards. Specification of composition and moisture content is a requirement here.

A product like lanolin (wool fat) would sometimes be used as fuel as well. Lanolin is indeed usable as bio fuel (Saacke bedrijfsinfo 2002), data on levels (and possible formation) of harmful substances have not been found (small volume). This also applies for other bio fuels such as vegetable and animal fats.

Ranking of contamination chances per type of fuel and per type of harmful substance.

As described above, the nature and composition of the fuel (including moisture content) mainly determines the contamination chance per category of harmful substance. The chance of the production of dioxins and PAHs increases in case of incomplete burning. In case of fossil fuels this is least likely in case of gaseous fuels and most likely in case of solid fuels. This is exactly the other way round for the formation of NO_x. Bio fuels are less concentrated, which means they have a lower burning value per unit of fuel (MJ/kg). This is even more the case if these fuels are not entirely dry. The level of heavy metals is also important. Contamination of feeding stuffs with metals during direct drying should (almost)

entirely be attributed to the metal level of the fuel.

Mixed municipal waste, mixed industrial waste and dried sewage sludge are and will remain formal waste products (report "Refuse Derived Fuel; current practice and perspectives, 2003). Member states of the EU can only issue a permit for use as fuel in special cases and for specific purposes. These waste products can unintentionally contain high levels of persistent contaminating substances. The use of it in a direct dryer cannot be tolerated because of these risks, but also from a GMP-HACCP point of view.

The assessment of the contamination chances of the dried product, because of transfer from the drying gases in the dryer, of dioxins, PAHs and heavy metals is further explained in appendices 1, 2 and 3.

For the evaluation of the chance of formation of harmful substances caused by fuels a separate list is needed per category of harmful substance (Appendix 4; Tables of contamination risks of fuels). The tables 1A up to and including 1D give an evaluation of the list of fuels per category of harmful substance.

Table 1A (dioxins) is explained in appendix 1; table 1B (PAHs) in appendix 2; table 1C (heavy metals) in appendix 3. Table 1D (NO_x) is largely derived from KEMA information. (KEMA, 2003). Table 2 (in appendix 4) gives an overview of the levels of heavy metals for various fuels.

Tables 1A up to and including 1D (appendix 4) have been drawn up on the basis of the analysis of incineration processes, which have been obtained from this study. The original numbers regarding emissions are converted into the formation of the harmful substance, expressed in weight to weight of converted fuel. The exception to this is NO_x, which is expressed in weight per volume of drying gas. The reason for this is that NO_x is partly formed from air nitrogen and is in many cases closer related to the burning temperature than the fuel composition. In the gases discussed and in case of light oil this is even the only source. The NO_x values which have been found for different fuels (table 1D, appendix 4) cannot be considered representative and indicative for the relevant fuels. This table only gives levels which were observed in practice and no risk assessments.

In order to be able to compare risks which are directly related to fuels, the chance of formation of harmful substances should be separated from the influence of processing and equipment. Therefore, it is always burning in "standard conditions" with an optimal conduct which is evaluated.

9.2 Burners / air heaters

Types of burners

The fuels, mentioned in 6.1, are transformed in the air heater (stove, "heater") of the dryer, to dry. The air heater and the actual burner inside are therefore the essential links between fuel and the process of drying.

The design, the construction, the state of maintenance and the conduct of the burner and the entire heater determine the completeness of the burning. And the risk of contamination of the direct drying gases with the rests of the fuel, unburnt contaminating substances

(POPs) and the “*novo*” synthesis of substances like PAHs and dioxins.

The used type of burner is closely linked to the fuel that can be used.

In fact, the present burner determines which fuels can be used for a long time (technical depreciation period). The combination of the construction of the burner and the fuel determines the physics of the combustion, which means an important part of the dynamics and the kinetics of it. The setting of the fuel: air ratio is an important factor while optimizing the combustion process.

In most burners/air heaters we make a distinction between “primary air” (for the primary burning) and “secondary air” (secondary burning) and sometimes “tertiary air” as an addition for the setting of the desired income temperature (T-in) and dry gas stream (flow) in the dryer (StelaLaxhuber KG-Homepage Produkte 2002).

Gaseous and liquid fuels are normally divided into very fine particles in the burner and are mixed with primary air and then burnt. Solid fuels, like coals and variations and bio fuels are usually burnt on grids or sometimes with a “fluid bed” or “fluidized bed” depending on the fineness (particle size).

In case of electric heating of drying air and heating via steam pipes or another heat exchanger, we talk about indirect heating. We will not discuss that here.

Burners for gaseous and liquid fuels.

A fine division of oil before the combustion is attained by means of several designs of burners, like e.g. “rotating cup” (Saacke Ltd.). A short overview of types and their actions is given in a RIVM/TNO report (RIVM/TNO 1993). The most advanced burners are “dual fuel”, so appropriate for both gas and oil and especially designed for guaranteed complete burning.

The limitation of the formation of NO_x plays a particular role when burning gas and oil.

In order to limit it, low NO_x burners are used. Gas burners of this type can reach 1 mg/m³ NO_x. This type (Ultra Low NO_x CXA) is offered especially for direct drying of food and feed (“GCD international”, 2003). There are also low-risk NO_x oil burners:

The proportions of NO_x in the drying gas are then a factor 5 lower than in case of burners without these facilities (KEMA, 2003).

Product information of suppliers of burners indicates that they pay a lot of attention to the completeness of the burning (e.g. in a two-stage burning process, during which there is a burning of gaseous remainders, also of persistent organo-chlorine compounds) and to the supervision of that (product information “Bloom engineering”, 2003). The burning conditions in these burners are designed in such a way that a temperature of maximum 1250 °C can be reached.

Burners for solid fuels.

Solid fossil fuels are brown coal, coke and several varieties of pit coal.

These burners are usually provided with grids on which a layer of fuel is laid. The combustion air is led through and over the fuel. It is essential that a sufficient temperature and full combustion is realised by a correct fuel-air ratio. A very effective combustion of solid fuels is reached by using a pulverised coal fluid bed, or cyclone burner in which (mostly) very fine pulverised coals are burnt in a strong turbulent air stream. However, this type is mostly found in power stations and other very large-scale heaters and waste incinerators.

Bio fuels can also be burnt very effectively using so-called cyclone burners (“Onyx corporation”; 2003). For example, this application works for wood clippings, looks like a fluid bed

and works very efficiently. Because of the design a combustion temperature of approximately 1100 °C is realised. This type of equipment however is expensive and cannot be found in the Netherlands and outside only sporadic in air heaters for dryers. In the Netherlands grid burners, in which the fuel is pushed into the furnace using a screw, are mostly used to burn wood (RIVM/TNO, 1993).

Burning solid fuels in burners that are not especially optimised for that use, increases the risk for harmful substances. This way we can globally derive from the estimated PAH-emission in the Netherlands by small-scale (domestic) multi-burners and power stations with pulverised coal gasification (KEMA, 2003) respectively, that burning waste in multi-burners (aimed on a large range of fuels, not on complete burning) can lead to the formation of PAH, which is a factor 100,000 higher than the industrial pulverised coal gasification.

9.2.1 Procedure of burners / air heaters

Setting the burning temperature

Burning at a high flame temperature will lead to the formation of NO_x because of the oxidation of air nitrogen by oxygen. In the product that must be dried, NO_x can lead to the formation of nitrosamines. (EU DG Industry, 1997; Scalan R.A., 2003). This is the fact for high-protein products, in which, on high temperature, free amino groups of the proteins react with the NO_x that is present in the drying air.

Meanwhile, there are special “Low NO_x” and “Ultra low NO_x” burners (for gas and oil), which can strongly decrease the formation of NO_x by regulating the flame temperature, or by injecting ammonia. These can certainly be recommended for direct drying, since they can seriously decrease the chance on the formation of nitrosamines. A too low burning temperature can lead to the formation of N₂O (KEMA, 2003). But this does not (as far as we know) influence the formation of nitrosamines since N₂O is no nitrosilating agent. The problems of the formation of NO_x by oxidation of air nitrogen is especially important in case of gaseous and liquid fuels, in which case very high flame temperatures can be realised in case of optimal burning. NO_x can also be formed from nitrogen compounds that are present in the fuel. This type of formation of NO_x is essential to the fuel characteristics and has been discussed in chapter 6.1.

The point of departure that NO_x (and SO_x) are considered a “hazard” in the HACCP (vertical risk analyses) and that (in most cases) it receives a seriousness classification “low”, must in our opinions be brought under discussion. Arguments for this are given in appendix 12. It has consequences for mentioning NO_x in the HACCP tables in the vertical risk analyses for several (groups of) feeding stuffs and for the risk calculation model.

The introduction of the ALARA principle for nitrosamines in feeding stuffs and thus for NO_x in drying air has (very probably) been the most important reason to almost completely replace the direct dryers by indirect dryers in the feeding stuffs industry.

Completeness of the burning.

Incomplete burning can, in principle, for all types of fuels, lead to the emission of aromatic hydrocarbons, soot formation (PAHs) and the formation of dioxins. Soot formation, during which small particles come into being, is one of the factors that strongly contribute to the

transfer to a product that must be dried. So the formation of soot is an indicator. PAHs can be formed inside and around the burner in case of insufficient burning. For dioxins it is so that the “novo” synthesis inside or after the burner is the most important mechanism (KEMA, 2003a; INSERM, 2001). It is exactly during the start-up of the burner and when the air supply does not work properly, e.g. due to bad settings, or lack of maintenance (incidental/ad hoc use of drying installations) that incomplete burning can arise. This will happen at the same time as the soot formation and CO-formation, which can both be measured in the line. The colour of the flame can also be used as indicator for the completeness of the burning and flame temperature.

9.3 Dryers

9.3.1 Types of dryers

Within the frame of this project, we will only pay attention to direct drying. Direct drying is a form of convective drying, which means drying by means of drying gas that flows by. In case of direct drying, hot drying gas with relatively low humidity is led straight over the product that must be dried, coming from the air heater. So there is direct contact with the feeding stuffs that need to be dried. Because of the heat transfer the temperature of the feeding stuffs and the evaporated water will be led away with the drying gas. There are a lot of variations on this basic principle (you can find a list in Van't Land, 1991), but far from all existing types of drying equipment are used to dry feeding stuffs. Obtained company information and gathered knowledge via company visits and interviews have (up to now) shown that only a limited number of dryers in industrial practice are actually used for drying feeding stuffs. These types are shortly discussed below to illustrate this. Steam dryers, contact dryers and radiation dryers are always heated indirectly and are therefore not discussed into detail. For an elaborate overview of types of dryers, go to the websites www.drying.de and www.stela.de. A list of manuals on drying techniques can be found on the website of the Dutch study group drying: www.drogen.nl.

The rotating tumble dryer

(“Simon dryers Ltd”; Swenson Technology, Inc.; “The Onyx Corporation”; “Stela Laxhuber”). Here the material that must be dried is entered on the top of a slightly sloping tube shaped tumble. Because the tube turns around and has blades on the inside, the material is repeatedly transferred to the other side of the tube. At the same time hot drying gas is led over the animal feed materials that need to be dried. This makes water come out of the material that needs to be dried by evaporation and the water will be removed via the gas flow. Drying according to the principle of counterflow, is energetically the most favourable, but contact between hot drying gas and a nearly dry product leads to burn risks. This is the reason why parallel flow is used in the usual tumble dryers. The rotating tumble dryer is suitable for a large number of different products (fibrous, granular and solid) and is one of the most used techniques for drying animal feed materials.

Conveyor dryers

(“Sakav” company information, Arrowhead 2003c)

The (solid) material that needs to be dried is placed on a (perforated) conveyor belt and is led through the drying compartment. During this passage the drying gas is led over and

through this conveyor. This type of dryer is among others suitable for drying coarse, fibrous products, including parts of plants (among others grass, Lucerne).

Vertical shaft dryer or going through dryer

("Van Aarsen International", "Geelen Counterflow", "Stela Laxhuber")

This drying technique is often applied in the mixed feed industry, but also for drying grain and corn products, immediately after harvesting. There are also mobile installations that can be used on the arable farm or near the storage silo. The solid material that must be dried is put through a shaft from above downwards and drying air is blown upwards in counterflow or in cross flow using inlet-outlet constructions. The temperature of the ingoing drying air is usually lower than for example in tumble dryers and spray dryers.

Floor dryer / bag dryer

This type of dryer consists of a perforated bottom plate on which the product that must be dried is put in gunny sacks or loose. Heated air is blown in the space under the perforated bottom plate and several types of air heaters can be used to heat up the air. For small blowers these usually are hot-air blowers, which are heated with butane/propane or paraffin oil. If paraffin oil or domestic fuel oil are used as fuel, the danger of pollution of the product with PAHs exists. This type of dryer is often used on a small-scale for farm products and is assembled locally. Process checking is often dropped or is very simple.

Spray dryers.

For this type, the liquid product is sprayed into a room together with a large quantity of hot drying gas, which means the product that needs to be dried is carried with the drying air. The water evaporates quickly because of the sprayed drops and a powder will be left. The powder is then separated from the drying air (cyclones or filters). There are several shapes of this type of dryer, including the spray tower and the box dryer. Spray drying is mainly used for dairy products, but also for starch, protein and blood products. Spray dryers are only used on large scale in an industrial environment.

9.3.2 Conduct of the dryers

Even though the conduct of the air heater/dryer is closely connected to that of the actual dryer, a number of risks can be influenced by specific process adjustments of the actual dryer, where contact with the product takes place.

Temperature profile of the dryer

The temperature profile in the dryer is determining for the interactions between the drying gas and the feeding stuffs that need to be dried, but also for autonomous processes in the drying gases, like condensation of burning products (metals) and chemical reactions (dioxins, nitrosamines). During the drying process the inlet temperature can be up to (and above) 500-600°C and the outlet temperature is mostly 100-130°C. The temperature decreased because of the evaporation of water from the product that must be dried.

So the temperature profile is determined by the inlet temperature, the capacity, the degree of humidity of the product, the transport of the product to be dried through the dryer and by the moisture transfer of the product to be dried to the gas phase. Change of these factors will influence the temperature profile in the dryer, but also from the product that needs to be dried itself.

Depending on the temperature progress in the dryer, dusts in the drying gas will condensate. This can be either on the surface of particles of fly ash or dust particles, or on the feeding stuffs that need to be dried. Both organic and inorganic elements are concerned. Fly ash and dust particles can also deposit on the product to be dried.

Dioxins can be formed in the flame in case of incomplete burning. They can also be formed in the drying gas in the cooling course between 200-500°C. In that case we talk about the "novo" synthesis of dioxins. The maximum is at approximately 350°C. If the drying gas remains longer in this temperature area, more dioxin will be formed. For the formation heterocyclic organic dusts are necessary and a relatively small amount of chlorine. The simultaneous presence of poly-chlorine and poly-bromine pollutions will seriously increase the formation of dioxins.

Contact temperature drying gas/product to be dried

In case of high temperatures of the drying gas, the product that needs to be dried can undergo analysis ("combustion"), especially on the surface of particles. This combustion can be perceived (microscopically as well) by the browning of the dried product and by the smell of fire. Under these conditions, PAHs can be formed in the product. The formation of PAHs also depends on the degree of proteins, fat and moisture in the material. For example, when grilling meat, during which hot air comes into contact with the surface, the amount of Benz[a] pyrene increases at factor 500 (Kazerouni et al., 2001).

Formation and deposit of fly ash

Fly ash comes into existence through fine division or evaporation, followed by condensation of minerals, coming from the fuel. This is mainly the case for solid fuels and heavy fuel oil. This very fine dust contains the heavy metals that have been released during the combustion and can also absorb any present PAHs and dioxins very efficiently (the absorption is not complete: there are also free PAHs). When fly ash is deposited on the product that must be dried, that means that these substances are transmitted. In case any heavy metals are present, capturing the fly ash (flue gas cleaning system) or other possible measures that prevent the deposit of fly ash on the product can strongly decrease the transfer.

Dust formation

Drying dust comes into existence during drying from the material that needs to be dried, among others due to mechanical wear and tear and to local overheating. Drying dust is in a number of cases, after the dryer, separated from the drying gas by means of a cyclone. The purpose is to limit the discharge of dust to the environment. It will be clear that carrying this dust towards the dried product involves risks. After all, fine dust contains overheated product and functions as adsorbent for present PAHs and dioxins. It will also possibly contain heavy metals. Therefore, the concentrations of unwanted substances in the cyclone dust can be considerably higher than those in the dried product.

9.4 Feed ingredients

Very wet products can form a closed mass, with a small surface, which is hard to dry. When leading the drying gas over the product that needs to be dried, this can cause crustation. This also hinders the drying process. It can even lead to the formation of large lumps or the product can get stuck to the dryer.

As a drying aid, additives are used that improve the product structure, increase the surface and make the products more accessible. Sometimes also substances that bind water themselves (like lime, clay, silica, hulls & husks). By creating a porous and enlarged surface the moisture transfer is improved. However, the chance of a transfer of contaminants from the drying gas will also increase. The most important risk of additives as drying aid (and "free flowing aid") is the direct pollution of the feeding stuffs by unwanted substances in the additives. Additives are not always tested sufficiently for this in our opinion.

As additives, often products that happen to be in the area of the drying house and have a low economic value are used. It is known that quicklime is used as an additive when drying humid citrus waste. This lime can (as proven) be considerably polluted with dioxins among other things.

Therefore, it remains possible that via polluted additives, harmful substances can get mixed up with the animal feed materials that needed to be dried. Microscopic evaluation can prove the presence of additives with sufficient sensitivity and can thus be used as control measure.

The experts consulted in phase 2 indicated hardly to know about the use of additives as drying aids. So no concrete examples were given other than the ones mentioned above. Apart from that, suppliers of feeding stuffs and suppliers of equipment were reserved in providing details that are evidently thought of as sensitive for the competition. It is well conceivable that the use of additives is also part of this. So everything stated above is still valid. The safety of additives must always be secured by a HACCP approach and a regular analytic control.

(also see 7.1 for the specific effect of alkaline additives on high-protein feeding stuffs).

10 Research results of project phase 2

10.1 Risks related to the product type and product composition

For a large number of raw materials vertical risk assessments (+ HACCPs) have been described (GMP 26a, 26b). The risk assessments have generic characteristics. These feeding stuffs are now divided into 15 groups, based on their origin and some dominant characteristics (page 3, GMP 26b, version 2003).

Another division would be based on the nature of the main components (high-protein, rich in starch, rich in fat, rich in NSPs, rich in minerals, etc.), the logistic origin (primary plant, industrially processed products or animal vs. vegetable), etc. The purpose of such a division would be to, if possible, relate drying risks to product types and/or product compositions. This could possibly be done based on the chance of synthesis of unwanted substances in the product that needs to be dried, under the influence of the drying temperature or from specifically depositing or absorbing dusts from the flow of drying gas. With that a better generic risk valuation would become possible. For example, it has been suggested that products that are rich in fat might have a higher risk of absorption of PAHs or dioxins.

During drying processes the product temperature will preferably be kept low to prevent depreciation of the product or, worse, fire in the dryer. In practice the product temperature will remain under 100°C during the main part of the drying course (where there still is free water) and will only possibly go over that temperature at the end. At these temperatures you can indeed talk about Maillard reactions and caramelisation but the formation of PAHs or dioxins still does not occur. In other words: the drying process can lead to the formation of some less desirable substances, but the consequences of that for the farm animals are very limited and there is no chain risk because the substances concerned are not transmittable. Here too we need to note that the appearance of caramelisation and Maillard reactions can lead to decolourisation of the product. The even higher temperatures that are necessary for the formation of PAHs and dioxins will certainly leave burning marks. A visual and/or microscopic investigation of the dried product will certainly show the presence of burning residues.

For high-protein products, two types of reactions seem relevant. The first is the possible formation of nitrosamines, influenced by the exposure to NO_x in the drying gases (see appendix 12).

The other is the possible formation of Lysine-Alanine complex (LAL) when heating high-protein products containing water in an alkaline environment. When using alkaline additives (lime) a measurable decrease of the protein quality can occur under normal time-temperature conditions. (www.fao.org/docrep). Both reactions however do not lead to "hazards" in the HACCP systematic and can be ignored in the risk analysis for direct drying.

The second potential risk regards the specific absorption of for example substances that are soluble in fat in materials that are rich of fat. This supposes that a balance will develop between the concentrations of these substances in the drying gas and those in the fat

phase of the product that needs to be dried. Section 6.2.3. indicates that substances like PAHs and dioxins are bound efficiently to fly ash and dust particles in the drying gas. That means that the concentration of the free form of these dusts in the drying gas will be limited. The largest part of the dioxin or PAHs that got mixed with the dried product will come from deposited fly ash and dust and will therefore not depend on the degree of fat in the material that needs to be dried. The literature has not given any foundations for the theory of adsorption of harmful substances from drying gas.

Based on these findings it has been concluded that there are not sufficient arguments to include product characteristics as e.g. the degree of carbohydrates, fat or proteins in the model as risk driver. That means that the sense of a group division for this expires.

10.2 Origin-related risks

The term “origin” in this section means the geographical origin of feeding stuffs. In Phase 2 of this study we have tried to find out whether the origin of dried products can be connected to specific risks concerning the drying processes they have undergone. We will present the findings below.

Asia: Tapioca, coconut and palm kernel are the biggest flows of raw material from Asia. Tapioca (chips) is sun and/or air dried and afterwards possibly pelleted (air cooling). When tapioca is artificially dried, there is a risk that the process will go too quick so the naturally present cyanogenic glycosides (limit of acceptability 100 ppm) are not completely decomposed. The risks of sun and air drying are microbial contaminations (pathogen bacteria), decay (if the process takes too long) and possibly the formation of mycotoxin when some specific moulds grow.

Especially in case of coconut (copra, flakes, powder) contamination with mycotoxins is a well-known problem. Most of the copra is sun-dried on a small scale and gets to the processing industry via collectors/traders. If the copra is dried artificially in the small-scale local production, the quality of the used fuel is sometimes too low. The installations are often very elementary. Industrial processors of coconuts (coupled to plantations) perform a little better as far as the risk on mycotoxin is concerned and as far as the PAH risk is concerned, but there are only a small number of them.

With regard to small-scale drying processes for collector products, these are often performed with great dedication, but the administrative foundations are (mostly) missing. It is also true that when one single lot does not meet the quality requirements, it is no longer significant because of the average, after the collecting phase. Structurally wrong process conducts in an area are noticed with standard quality analyses. The collector can (and will) then act correcting. So the risk for the European consumer of these products is small. On the other hand, it has been noticed that the traceability sometimes falls away and the largest risks arise at that moment; since nobody is approachable anymore. So traceability and approachability of the collector are essential in this case.

Oil palm products are mainly industrial by-products, expellers (flakes), which are pressed, and not dried, and palm kernel grist. The palm kernel grist are extracted and dried; this production is limited and does not expand.

Asia is an increasingly important source of Soy (non GMO), in the shape of beans, flakes, grist and hulls, and to a lesser degree rapeseed, rape flakes and rape grist. The grist of these products are dried; especially in India this is a small-scale process.

For the whole of Asia it is better to use light oil to heat a fire; the smaller the process, the more risks the fuel will entail. The less thriving the region, the larger the risk.

Australia: This area supplies lupines and (sometimes) grains. These primary arable crops are (on a reasonably large scale) dried on the farm yard or regionally by means of shaft dryers. The fuel is normally light fuel oil. The equipment and conduct of the process is of the same quality as in Western Europe.

Africa: The flow of feeding stuffs from Africa is very limited. Palm expellers and peanuts are mentioned. The circumstances can be compared to less thriving areas in Asia and thus the risks as well. Peanuts and the by-products – flakes and grist – are known for their aflatoxin risk; that is why it is not often used as feed additive.

North America: This area supplies considerable amounts of primary arable crops like peas, rapeseed (limited), canola, linseed, soy and corn and by-products of corn, soy, grain, citrus and beets, both from production on a large-scale and on a small-scale. The legal regulations are of good quality as well as the mentality in the companies and of supervisors. Equipment, conduct of processes and risks are generally comparable to Western Europe.

South America: South America is an important supplier of raw materials for the Netherlands. The feeding stuffs that are imported from South America are soy (beans and soy products), sunflower (seed and grist), citrus pulp, peanuts (flakes and grist) and rape (seed, flakes, grist). The most important suppliers are Argentina and Brazil. In Argentina almost all dryers are gas heated, modern installations.

In Brazil we find oil or wood heated dryers. The wood often comes from special plantations; normally there is a good separation between burning wood and waste wood. The risks of PAHs and dioxins are comparable to those in Western Europe, under the condition that the wood is dry enough.

Europe: Source for linseed (especially as defatted by-products), grains, sunflower seeds, rapeseed and their defatted by-products. Western Europe is regarded as the standard against which the risks in other areas are assessed. There are of course differences within Europe. Central Europe has all types of dryers; Southeast Europe generally has old (obsolete) equipment. The calculation model that was developed in this study sufficiently maps the risks that occur here.

Outside the tropics, it is a fact that for grains and seeds the wet harvesting seasons (years) are an extra risk because the available drying capacity generally has shortcomings. The risks are rather contamination with mould toxins and decay than PAHs, PCB etc.

The conclusion from the above is that Phase 2 of this study has not delivered any univocal foundation to put the geographical origin of the feeding stuffs in the model as risk driver. However, it has been signalled that in areas where the circumstances are poor and the status of the feeding stuffs shifts from “product” to “commodity”, the risks of contamination increase. This problem can only be overcome when people can be held accountable for that.

11 Control measures

These are aimed at:

1. The composition of the fuel.
2. The design and execution of the incineration process.
3. Temperature time course of contact of the product with the drying gases.
4. Additives and cyclone dusts.

Ad 1.

Fuel specification

Fuels and their composition form an important source of serious risks when directly drying feeding stuffs. These risks can be controlled by solely buying fuels with a known and relevant specification of well-known origin. A regular check of the offered specification by means of analysis is necessary. The type of fuel must match the fuel specification of the burner. The logistics of the fuel must be secured by a HACCP process.

Ad 2.

Burner settings

Flame temperature, air/fuel ratio and air/fuel division determine the completeness of the burning. This is very important to prevent the formation of PAHs, dioxins and NOx. Depending on the type of burner the preventive and operational measures must be taken in order to let the burning pass as optimal as possible. These must be set down in a GMP protocol for each installation. Starting and putting out burners forms an extra risk, for which proper SOPs must be present (possible parallel drain of combustion gases, not via the dryer).

CO measurement and soot evaluation.

CO arises in case of incomplete burning and can be measured online. Within a process there is a clear connection between CO and dioxin in the drying gas. In case of a failure in the burning process, because of a decrease of the air supply for example, the burning can be incomplete for a while. The same is true for the formation of soot. Soot in cyclone dust and others indicates an incomplete burning. Soot formation in the burner can be measured continuously; there is good equipment for that.

Cleaning of drying gas before the dryer

Drying gas can already contain particles of fly ash in the beginning of the dryer.

In electricity production, standard cleaning of flue gas is used to decrease the emission. It appears that drying gas cleaning can remove a part of the PAHs, 75% of the dioxins and nearly all heavy metals.

Drying gas cleaning has not been found yet in the drying sector. Requests at a manufacturer of dryers (the onyx company) has taught that they are looking for the control on the level of burner settings, fuel choice and fuel analysis.

Drying gas cleaning can be seen as an additional possibility to limit the chance of contamination of the feeding stuffs that need to be dried by approximately 75%.

Ad 3.

Conduct of the dryer

The conduct of the dryer has a large influence on the pollution of the product that needs to be dried with unwanted substances. The control measures that must be taken depend strongly on the type of dryer (temperature profile, how long the product remains inside). They must be described in a specific GMP protocol for the dryer in question.

Visual inspection of the dried animal feeding stuffs

If the contact temperature is too high, this can lead to burning of the product and to the creation of unwanted substances. This can be observed by the dark colouring of the product and the smell of burning. This organoleptic inspection must be performed regularly as a control measure. An magnification of 10 - 20 x strongly improves the distinguishing capacity of visual control.

Ad 4.

Presence of additives.

Some substances might have been added to the product that needs to be dried to improve the drying process and/or the structure of the dried product. The nature and composition of the product must always be mentioned in the product specification and the HACCP of the dried product. Additives can also mostly be detected and often even identified by visual (microscopic) inspection.

Presence of cyclone dust that has been led back

Cyclone dust is dust that is formed during the burning and/or drying process and that is caught after the dryer to prevent emission to the air. Cyclone dust often contains higher degrees of unwanted substances than the main stream of the dried product. So leading the cyclone dust back to the dried product is not advisable for this reason, except if it can be proven that the amount of unwanted substances in the cyclone dust remains within the norms for the product in question (feeding stuffs). The presence can mostly be determined by visual inspection.

Not being able to lead the cyclone dust back to the product can cause a considerable practical problem for the drying house, since they will have to find another way of disposing of it.

12 Operation of the HACCP calculation model

For this calculation model, Excel software is used to calculate risks. This calculation model calculates the risks of unwanted substances, PCBs, dioxins, poly-aromatic hydrocarbons (PAHs) and heavy metals. NOx (in connection with possible formation of nitrosamines) has eventually not been included because the quantification of the risk, based on the available data, was not possible (appendix 12). For the calculation of the risks, HACCP systematics are used, which means that the chance of presence is multiplied with the severity of the unwanted substances (risk = chance x severity).

HACCP model

Risk	Severity		
likelihood	<i>Minor</i>	<i>Moderate</i>	<i>Major</i>
<i>Very low</i>	1	1	2
<i>Low</i>	1	2	3
<i>Moderate</i>	2	3	4
<i>High</i>	3	4	4

The HACCP model above has been taken from the HACCP systematics of the PDV, but extended with the "very low" likelihood of occurrence. This was done because, according to the existing systematics in case of an indirect drying process, during which there is no contact between burning gases and the drying product, a risk 3 (PVA, point of attention) for dioxins could arise. This is not according to reality.

The calculating model counts with risk factors that could influence the likelihood of presence of unwanted substances. The used formula consists of dependent and independent risk factors. For risk factors that influence each other, like fuel and burner type, the relevant likelihood scores are multiplied. The risk factors that do not influence each other, are added. As shown by previous studies (a.o. RIKILT), there are a number of so-called "Risk Drivers" among the risk factors. These mostly determine the likelihood ("very low", "low", "moderate" and "high"). In the model, the risks: D through I. The other risk factors mainly cause that in case of a marginal case the chance will just belong to a next category.

The total likelihood score is calculated as follows, by means of the likelihood scores of all risk factors:

$$\text{Total likelihood score} = A + B + C + (D \times E \times F \times G \times H \times I) + J + K + L + M$$

Whereby

A = process information

B = land of origin (see internal table in EXCEL calculation model)

C = use of additives

D = type of drying process (see internal table...)

E = type of fuel (see internal table...)

F = fuel check

G = type of burner (see internal table...)

H = burner settings and temperature

I = flue gas purification before drying

J = return dust or ash fractions

K = monitoring CO level

L = check for formation of soot

M = check for smell/colour

Type of product was a risk factor in an earlier version and has been omitted based on research results from Phase 2.

- A. Process information:** If no information is known about a drying process, this calculation model will calculate with a higher chance on the presence of unwanted substances and the other selections in the model will be blocked since no process information is available on this.
- B. Land of origin:** If no process information is known, it is still possible to choose the land of origin, which means that for some countries a higher risk of presence of unwanted substances will be taken into account.
- C. Use of additives:** Because of the use of additives the surface of the product that needs to be dried is enlarged, which also increases the chance of adsorption and thus presence of unwanted substances.
- D. Type of drying process (*Risk Driver*):** If there is no contact between burning gases and the product that needs to be dried, the chance of presence of unwanted substances in the dried product is "very small". *Be careful: Unwanted substances can enter the product by transfer and/or formation during the drying process in this model. This does not guarantee that these unwanted substances were not already present in the product when it was still "wet", so before drying.* When this choice applies a couple of other choices from the calculation model expire, since they are no longer relevant. If however there is contact between the burning gases and the product that must be dried, the model will take a higher risk of presence of unwanted substances into account.
- E. Type of fuel (*Risk Driver*):** Based on the emission data for the different fuels, each unwanted substance is calculated with different likelihood scores.
- F. Checking the fuel (*Risk Driver*):** Checking the composition of fuels can prevent that for example light fuel oil which is polluted with used motor, transmission or thermal oil is used. The analysis of fuels gives insight into the quality of the fuel, so that, in particular, the risk of presence of heavy metals, organ chlorine compounds and PCBs can be decreased.
- G. Type of burner (*Risk Driver*):** A low NO_x burner reduces the chance of NO_x by 75%, a grid burner reduces the chance of heavy metals with approx. 80%, because in this type of burners an ash fraction of approx. 80% remains.
- H. Burner settings and temperature (*Risk Driver*):** A regular check of the burner settings and flame and course temperature reduces particularly the risk of incomplete burning and thus of the formation of dioxins and PAHs.
- I. Flue gas purification before drying (*Risk Driver*):** Literature has shown that flue gas purification can achieve a reduction of approx. 75% for unwanted substances that are connected to fly ash, such as PCBs, dioxins, PAHs and heavy metals. Flue gas purification before the dryer does not effect NO_x.
- J. Return dust or ash fractions:** Adding dust or ash fractions to the dried product increases the chance of dioxins and heavy metals, and to a lesser degree PAHs.
- K. Monitoring the CO level:** Online measuring of the CO level gives insight into the occurrence of incomplete burning and failures and enables quick corrections. If this does not get measured, there is a larger chance of dioxins and PAHs.

- L. Check for the formation of soot:** Continuously checking for soot formation gives insight into the occurrence of incomplete burning and enables quick corrections. If this does not get checked, there is a larger chance of dioxins and PAHs.
- M. Check the smell and colour:** A regular organoleptic check of the dried product as far as smell and colour are concerned, together with regular chemical analyses, gives insight into the risk of the formation of PAHs and to a lesser degree of nitrosamins. If the drying temperatures are too high, the product can get burnt, which makes that the risk of PAHs strongly increases. The formation of nitrosamins increases in case of strong heating of high-protein products if there is NOx.

Based on the given information of the dried product and the choices in the calculation model, the total likelihood score is calculated. In order to translate the calculated likelihood score into a chance evaluation according to the HACCP model, the total likelihood score is translated by means of the table below:

Total likelihood score	Likelihood according to the HACCP model above
≤ 100	<i>very low</i>
> 100 and ≤ 1,000	<i>Low</i>
> 1,000 and ≤ 10,000	<i>Moderate</i>
> 10,000	<i>High</i>

Use of the HACCP calculation model

For the HACCP calculation model we have chosen for Microsoft Excel 97. For the user the calculation model is presented on the display as a simple filling in exercise, in which drop-down menus with selection options are used. The calculation model is protected against improper use and manipulation. By clicking on one of the selection possibilities from the drop-down menus, a likelihood score is assigned in each of the three columns of the unwanted substances (dioxins, PAHs, heavy metals). Advices and control measures for the manufacturer of the dried product are also mentioned.

After having completely filled in the calculation model, the risk is determined and advice and control measures for the customer/user of the dried product are presented.

Use the orange button to print:

(This makes that the model is printed on a blank background.)

Print page

An output print of the risk model (version 4) has been included as Appendix 8.

Disclaimer:

This HACCP calculation model is solely meant to make a quick and systematic first risk analysis of a drying process that is applied to feeding stuffs. This is based on essential

information that is available (or should be) concerning the applied drying process. Based on the analysis control measures can be presented that follow directly from the risks that are identified by the calculation model. Both the result from the risk analysis and the presented control measures are determined by assumptions and weighing factors in the calculation model. These can only present a very simplified image of reality and besides, they are based on insights and knowledge that was available when drawing up the model. The model only analyses the risks of one specific drying process in the production sequences of feeding stuffs. So successive drying processes in the production sequence (if applied) must be analysed separately and must then be combined by the judge to a total risk analysis for all drying processes in that chain.

The result of this risk analysis may exclusively be used as a serious indication for present risks, missing information and control measures that should be taken. No rights can be derived from the result of an analysis with this calculation model. Conclusions based on analysis with this calculation model are always inferior to a complete HACCP analysis by an expert auditor.

13 Conclusions and recommendations

13.1 Conclusions

1. Based on the systematic research, performed in project phase 1, it can be concluded that direct drying can be a well-controlled process that can deliver a safely dried product, provided that it is performed in compliance with GMP and HACCP principles as indicated in this report.
2. In case of professional and meticulous execution (GMP and HACCP), "direct drying" will not lead (in case of the products and situations that have been studied so far) to considerable or unacceptable contamination of the dried feeding stuffs (animal feed materials) with substances that can be dangerous for the health of the animal, those who handle the products and the food chain (in particular animal food products).
3. The following have been identified as the most important hazards and risks for the product safety in case of "direct drying" ("Risk Drivers"): fuels, type of the burner, conduct of the burners (the burning process) and the conduct (conditions) of the actual burner. Additives (if applied) and returned drying dust are identified as possible additional risks that demand special attention.
4. The fuels that have been examined in this study (up to now), both fossil and biological, can in principle be allowed, provided that it is guaranteed that they are not contaminated and dry, that they have been delivered according to specification and are guaranteed by an HACCP procedure.
5. In this study, no recommendations are given for minimal specifications (maximum levels) for the different fuels for direct drying. Concrete figures on levels in fuels and actual observed transfer to the feeding stuffs to be dried, are missing as yet. The collected information on common compositions of several fuels, in combination with the standards that are laid down in the Netherlands and in the EU among others, appear a good basis to draw up a temporary recommendation based on attainable "best practice" principles.
6. Waste products, regardless of their nature, may never be used as fuel for "direct drying". They may also never be added to or mixed with fuels for direct drying. The use of this as fuel or in fuel for direct drying should be prohibited in our opinions, insofar as this is not yet the case for use as fuel in general.
7. A well-designed and carefully executed conduct (process control) of the air heater/burner unit according to GMP and HACCP principles is essential for controlling the risks of a "directly heated" drying process. A SOP must be part of this to start up and switch off the installation and for failure situations in which the conduct of the process can no longer be controlled. The technical possibilities for "real time" (in line) monitoring and optimisation of the burning process are available.
8. Based on the information that is available at the moment it has been found that flue gas purification after the burner and before the actual dryer is not (or hardly) applied. Flue gas purification at high temperature requires costly equipment, which is apparently not

justified based on the (low) risk level that can be realised with other control measures against the identified “Risk Drivers”.

9. Additives (as aids during the drying process) are not part of the thermal drying process but are sometimes used during that. Additives can be used during both direct and indirect drying. They must always be mentioned in an HACCP analysis, and in the product specifications of the dried products, since they can form a serious risk to the safety of the dried feeding stuffs.
10. Returning ‘cyclone dust’ (the dust fraction that can be caught in the exiting drying air of directly heated dryers) in the dried product causes an additional (not yet quantified) risk. Returning this “cyclone dust” is in our opinion only acceptable if the amounts of unwanted substances in it do not exceed the standards for the corresponding dried feeding stuffs (during the drying of which this dust was released).
11. Drying processes for feeding stuffs may look simple, but from a HACCP point of view they are complicated. The identification of possible dangers (“hazards”) can still be performed generically for an important part. (Phase 2 of this project)
However, the final risk analysis for a certain dried feed additive must be specific for unique “product installation combinations” as they can be found in practice. Therefore this must be performed according to each specific process.
It can be very misleading to comment on specific processes, without knowing the details of them and having systematically evaluated them.
12. In this study, it has not been possible to find a valid relation between the composition of feeding stuffs (most important macro-components) and the specific risks during the drying process by means of direct drying. It is only for “high-protein” feeding stuffs that some relations have been found, which do not result in a “hazard” according to the HACCP systematics. The “product type” (product group) has for that reason not been included in the calculation model as “Risk Driver”.
13. The HACCP calculation model for “direct drying” feeding stuffs that has been developed in this project seems to be a good workable and easily manageable aid to perform risk analysis for a large range of practical situations in a systematic way.
The validations that have been performed until now (limited number), by means of known practical situations, indicated that a realistic estimation of the risk can be obtained for these situations. The underlying dataset (internal tables, calculation model) however is not elaborated enough to be able to perform reliable risk estimations in the full diversity of the feeding stuffs that are imported, offered and used in the Netherlands. Also the background information on a number of contaminants, processes and risks is not completely clear yet. Further completion based on new information after the conclusion of this project is possible and advisable. The gaps are in particular:
 - drying situations outside the reasonably known industrial environment of Western Europe and North America (small-scale and local drying processes according to traditional methods among others) and
 - the direct causal and quantitative relations between the process circumstances and the final risk, based on described processes (both process type and process conditions) and measured amounts of contaminating substances.(also see par. 5.2.2. : Actual knowledge gaps).

14. The expectation that a good insight into the risks of drying processes, performed outside of the known agro-industrial infrastructure of Western Europe and North America, by means of interviews with experts, would be received in Phase 2 of this study is only partly confirmed.
Especially the supplying industry (of feeding stuffs and equipment) seemed to be very reserved about supplying this type of information (that could possibly influence competition and image).
15. The companies that purchase feeding stuffs (animal feed industry and trade) will have to go deeply into the processing used by their suppliers of feeding stuffs (animal feed materials), more than they used to, to be able to perform effective estimates and thus realise their HACCP approach.
16. The generic vertical risk analyses of the PDV and the calculation model that has been developed in this project are good and complementary aids to do that (these supplier evaluations may also be contracted to experts).
17. Based on the starting points for the GMP & HACCP systematics for feeding stuffs, the doubt whether NO_x and SO_x in drying gases must be seen as a "hazard" arises. It is true that NO_x can lead to the formation of carcinogenic nitrosamines in feeding stuffs, but there are no indications that the maximum found amounts form a danger to the health of the animal.
Nitrosamines in animal feeds are (insofar known) not transferred to the food chain, and thus do not form a danger for the consumer of animal products.
In the production of foodstuffs (for human beings) the ALARA principle (As Low As Reasonably Achievable) is used, since no safe No Effect Level can be set for these substances. This dilemma begs for a solution.
In our opinion there are also no indications that SO_x in drying gases must be seen as a "hazard". It can however have a negative effect on the nutritional value of the product, by the inactivation of nutrients. This doubt also exists for LAL.

13.2 Recommendations

1. During this study it has been found that in the world only a few independent and scientifically reliable studies have been published, which enable a systematic risk evaluation of the drying process of feeding stuffs. The project team recommends initiating independent research into the actual deposit of unwanted substances in drying gases in directly heated dryers, in relation to the composition of these drying gases, the used fuels and burner technology, the conditions in the dryer and the composition of the feeding stuffs.
2. In our opinion the PDV will have to reconsider the "hazard" status of NO_x and SO_x and LAL (and in some analyses DMNA as well) and the conclusions of this study with respect to these contaminants.
3. If NO_x in drying gases and nitrosamines in feeding stuffs are regarded as "hazard" in the framework of the GMP and HACCP arrangement for animal feed, the amounts of

these substances that are found in practical drying installations and the effectiveness of measures (like Low NOx burners) to minimize the risk based on this “hazard” must immediately be studied.

4. In the future the Database of Risk Assessment of Feeding stuffs will contain information that will make it possible to complete the dataset that is already built-in in the HACCP calculation model for “direct drying”. Specific process research could also deliver new information. The PDV should in our opinion take the initiative to include (or to have included) new available information to this dataset, so that the validity and the accuracy of the calculation model is improved.

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15 Glossary

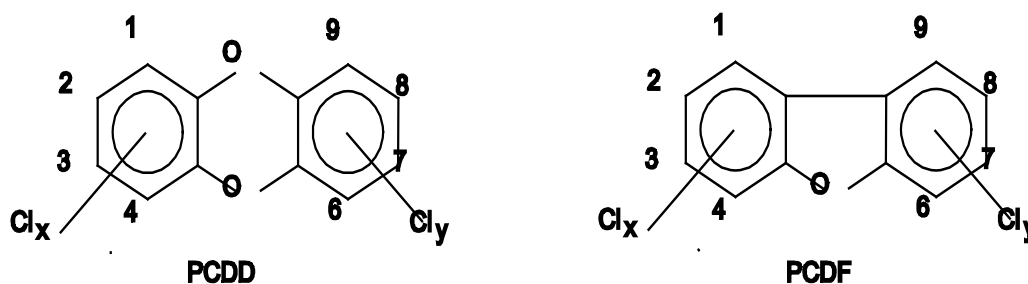
Waste products: Each substance (or each object) that the user throws away, or plans to throw away or must throw away. It is not because the consumer is ready to pay for a substance that is released during a process, that it is not a waste product. The demarcation between waste product, raw material and product is a pressure point, also because there is ambiguity as far as the interpretation of these concepts is concerned.

Supplementary heating: Adding a limited amount of an extra (biological) fuel to a fire which is mainly heated with another fuel.

Animal feed materials / feeding stuffs: Products of vegetable or animal origin in natural state, fresh or preserved and the derived products of their industrial processing, as well as organic and inorganic substances, either a mixture or not, with or without additives and intended for animal feed via the oral way (Regulation PDV animal feed 2003, in accordance with guideline 79/373/EU).

Direct drying: All drying processes during which the flue gas of an air heater has contact with the product that must be dried during the drying process. A form of convection drying (Direct-fire drying). Not to be confused with: **Indirect drying:** All drying processes during which no flue gas has contact with the product that must be dried during the drying process. Several forms of convection drying with indirect heating, contact drying, radiation drying and vacuum drying.

Dioxins: Collective name of PCDD (polychlorine dibenzodioxins) and PCDF (polychlorine dibenzofuran). Both classes contain a large number of congeners. Structures are appended.



DMNA: Dimethylnitrosamine, nitrogen compound that belongs to the group of the nitrosamines, formed among others by a reaction of NO_x with free amino groups of the material that must be dried. Carcinogene dust.

HACCP: Hazard Analysis of Critical Control Points. A process during which all connections in the production process are systematically analysed and the potential hazards for product quality and product safety are identified and described (Definition General GMP stan-

dard animal feed sector GMP01; 12-11-2003).

Horizontal risk analysis: Identification of critical steps during comparable steps while processing products.

Air drying: Natural or artificial drying process during which only unheated air is used to dry.

MER: Milieu-Effect-Rapport (Report on the effects on the environment): A public document, in which an intended activity and alternatives that must be considered with reason, the effects on the environment that can be expected in their mutual connection are described in a systematic way and as objectively as possible.

NOx: is the chemical abbreviation for “nitrogen oxides”. It is a collective name for the compound between nitrogen and oxygen. The most common nitrogen oxides are NO and NO₂.

PAHs: Poly-Aromatic Hydrocarbons, collective name for substances with more than one condensed aromatic ring, but apart from that a very diverse structure. Carcinogen PAHs appear to have 4 to 6 benzene rings and the mutagen PAHs appear to exist primarily of structures with 4 or more rings. This means that only the less volatile PAHs, starting from 4 rings, are important from a health point of view. These forms are mainly connected to very small dust particles, so-called aerosols.

The Dutch government policy with respect to PAHs particularly refers to a group of ten PAHs: Naphthalene, anthracene, fenanthrene, fluoranthene, *benzo(a)anthracene*, *chrysene*, *benzo(a)pyrene*, *benzo(ghi)perylene*, *benzo(k)fluoranthene* and *indene(1,2,3-cd)pyrene*. The PAHs in italics are proven to be carcinogene (KEMA, 2003).

PBBs: Poly bromine biphenyl; collective name of brominated biphenyl. The separate substances are congeners of each other, molecules with the same basic structure but separate characteristics.

PCBs: Poly chlorine biphenyls; collective name of chlorinated biphenyls. The separate substances are congeners of each other, molecules with the same basic structure but separate characteristics.

PCTs: Poly chlorine phenyls; group of substances connected to PCBs in structure and characteristics.

Risk Driver: A factor that largely contributes to the risk that is connected to a process.

SOP: Standard operation procedure; a written procedure as laid down by ISO, GLP and GMP procedures.

SOx: is the chemical abbreviation for sulphur oxides. SO₂ is the most common.

Additives: Substances that have been mixed in the feeding stuffs during the drying process, as technological aid, to make the drying process run more efficiently.

Vertical risk analysis: Identification of critical steps while processing a product.

WHO-TEQ: Toxic Equivalent Quantity according to WHO standards. System to congenate the amount and toxicity of PCDF and PCDD and to express a number of PCBs in one weight number, for which the most toxic congenate 2,3,7,8-TCDD is reference (INSERM, 2000).

Sun drying: Natural drying process, during which the product is dried in open air (Cornelius, 1973).