# MAIN AGENTS AND CONTAMINATION PREVENTION IN ANIMAL FEED INDUSTRY: REVIEW

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**ABSTRACT:** The main physical, biological and chemical agents involved in cross-contamination are of known origin, generally harmful and toxic, which ends up making the individual have direct or indirect contact with the nutrients used in the manufacturing of animal feed. The knowledge of the causes, as well as their different forms of prevention and corrective actions, allow us to minimize losses in animal yield and possible extra costs in production due to the need to prevent the spread of pests and diseases to human health. Failure in monitoring the Good Manufacturing Practices (GMP), Standard Operating Procedures (SOPs), and Hazard Analysis and Critical Control Points (HACCP) systems due to lack of trained personnel or bad structural conditions of the industry are the main causes of cross-contamination. In this sense, diagnosing risks and controlling critical points in the production process are essential tools. Thus, this review aims at emphasizing the main forms of cross-contamination in the animal feed industry and the care that must be taken at the factory to minimize cross-contamination.
**KEYWORDS:** Animal Feed. Legislation. Prevention. Quality control.

## PRINCIPAIS AGENTES ENVOLVIDOS E FORMAS DE PREVENÇÃO DA CONTAMINAÇÃO NA INDÚSTRIA DE ALIMENTAÇÃO ANIMAL: REVISÃO

**RESUMO:** Os principais agentes físicos, biológicos e químicos envolvidos na contaminação cruzada são de origem conhecida, geralmente nociva e tóxica, que acabam fazendo com o diretor contato indireto com os nutrientes utilizados na fabricação de alimentos para animais. O conhecimento das causas, formas diferenciadas de prevenção e ações corretivas, permite minimizar as perdas no desempenho animal e, possíveis custos extras de produção, pela necessidade de evitar a propagação de pragas e danos à saúde humana. Falhas no monitoramento das Boas Práticas de Fabricação (BPF), Procedimentos Operacionais Padrão (POPs) e do sistema de Análise de Perigos e Pontos Críticos de Controle (HACCP) por falta de pessoal treinado ou más condições estruturais na indústria do contexto físico são as principais causas da ocorrência de contaminação cruzada. Nesse sentido, diagnosticar riscos e controlar pontos críticos no processo de produção são ferramentas indispensáveis. Dessa forma, o presente artigo de revisão visa destacar as principais formas de contaminação cruzada na indústria de ração animal e os cuidados que devem ser tomados na fábrica para minimizar a contaminação cruzada.
**PALAVRAS-CHAVE:** Alimentação animal. Controle de qualidade. Legislação. Prevenção.

## PRINCIPALES AGENTES INVOLUCRADOS Y FORMAS DE PREVENCIÓN DE LA CONTAMINACIÓN EN LA INDUSTRIA DE ALIMENTOS PARA ANIMALES: REVISIÓN

**RESUMEN:** Los principales agentes físicos, biológicos y químicos involucrados en la contaminación cruzada son de origen conocida, generalmente nociva y tóxica, que terminan haciendo contacto directo o indirecto con los nutrientes utilizados en la fabricación de alimentos para animales. El conocimiento de las causas, las formas diferenciadas de prevención y las acciones

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correctivas, permiten minimizar las pérdidas en el rendimiento de los animales y, posibles costos extras de producción, por la necesidad de prevenir la propagación de plagas y daños a la salud humana. Fallas en el monitoreo de las Buenas Prácticas de Fabricación (BPF), Procedimientos de Operación Estándar (POE) y del sistema de Análisis de Peligros y Puntos de Control Críticos (HACCP) por falta de personal capacitado, o malas condiciones estructurales en la industria del contexto físico, son las principales causas de la ocurrencia de contaminación cruzada. En ese aspecto, diagnosticar los riesgos y controlar los puntos críticos en el proceso de producción son herramientas indispensables. Así, el presente artículo de revisión pretende evidenciar las principales formas de contaminación cruzada en la industria de alimentación animal y los cuidados que deben ser tomados en la fábrica para minimizar la contaminación cruzada.
**PALABRAS CLAVE:** Alimentación animal. Control de calidad. Legislación. Prevención.

## 1 Introduction

Rationing care starts from grain production, transportation, storage, quality and processing to feed the animal. The Ministry of Agriculture, Livestock and Feed Supply (MAPA) (BRASIL, 2007) elaborated in Normative Instruction (NI) 4/2007 of 03/01/2007, for Brazil, the Technical Regulation on Sanitary Conditions and Good Manufacturing Practices for Establishments Manufacturers of products destined to the Animal Feed.

The contamination is define as the presence of foreign substances or agents of physical, biological or chemical origin which are considered to be harmful to animal health and cross-contamination, all types of contamination of products intended for animal feed with another one during the process contamination caused by improper contact of the contaminated ingredient, raw material, surface, environment, people or products, which may affect the safety of the final product (BRASIL, 2007).

The most common physical contaminations occur by the presence of foreign materials, such as other grains mixed with inputs, pieces of wood and metal, among others. The most common biological agents are brought in the production for the animals almost imperceptibly by the presence of pests (ATUNGULU *et al*., 2016 ), domestic animals, wild animals and / or contaminations in the field and industry by pathogenic microorganisms such as fungi, bacteria and viruses, which can be eliminated by controlling the temperature and humidity (ATUNGULU *et al*., 2015).

Cross-contamination by chemical agents usually occurs due to the undue presence of hygiene materials in the industry and residual pesticides treatments in the field (O'MAHONY, *et al*., 2012).

The NI 4/2007 of the MAPA presents indispensable rules for the elaboration, industrialization and storage of products destined to animal feed. They cite the Good Manufacturing Practices (GMPs), Standard Operating Procedures (SOPs), and Hazard Analysis and Critical Control Points (HACCP). Systems that deal with hygienic, sanitary and operational procedures applied throughout the production flow, from obtaining the ingredients and raw materials to the distribution of the final product, as well as specific prevention and control plans, with the objective of guaranteeing the quality, conformity and safety of products intended for animal feed (FDA, 2017).

The concept of quality is quite broad, however, the quality control program in the animal feed industry can be understood as the set of actions that aim to ensure that the final product is as close as possible to the specifications or standards established (COUTO, 2008). This review aims to identify the main forms of cross-contamination in animal feed industry, as well as the most used ways to avoid and/or correct this contamination.

## 2 Development

In Brazil, the regulation and inspection of products intended for animal feed is the responsibility of MAPA. In 2007, with the implementation of NI 4, the regulation that defines the basic procedures of hygiene and GMPs for processed and processed feed for animal consumption, which proposes an industrial inspection roadmap (BRASIL, 2007).

International information and regulations corroborate with Brazilian requirements regarding animal feed, citing that packaged or bulk feed should be stored for distribution in a way that does not cross-contaminate with other products and raw material of animal origin (FDA, 2017).

The main irregular points observed were related to aspects of hygiene and process flow, which could contribute to the presence of microorganisms and chemical residues in the industry, causing cross-contamination in the animal feed (VAN SCHOTHORST; OOSTERROM, 1984; JONES; RICHARDSON, 2004; TORRES, *et al*., 2011).

### 2.1 Physical Contamination

#### 2.1.1 Dust

The presence of dust is the main means for physical contamination observed in the feed industries. In the factories studied by Jones (2002) it was verified the presence of dust and internal incrustations in equipment, evidencing the difficulty of its control during the process. The dust produced during the production of the feed tends to remain in suspension, depositing later inside the equipment and the facilities.

The acceleration required for grinding the grains in the mills favors the production of heat, which contributes to the condensation of moisture and formation of incrustations. This causes cross-contamination by the deposition of several different ingredients during the production of the rations and also provides an environment conducive to the proliferation of pathogenic microorganisms. Similarly, conveyors and elevators favor dust dispersal and the occurrence of cross-contamination by air in the external area and transport (JONES, 2002).

Studies on the evaluation of samples collected in animal feed industry showed a higher incidence of total coliforms in dust residues (JONES; RICHARDSON, 2004). The use of filters in equipment with high production capacity and accumulation of dust can be an alternative for the retention of fine particles in suspension (STARK; JONES, 2010) however, cleaning and filter replacement should be carried out whenever necessary, according to the conditions of the equipment to be effective. Variables such as the design of

the plant, dust and contact with the external environment can influence its recontamination, even with strict control (WIERUP; HÄGGBLOM, 2010).

**2.1.2 Pests**

In fact, the present pests can commonly be found, like the insects in the corn deposited in bulk, which infest the corn grains, causing losses of weight and energy in the grains (ELIAS *et al*., 2009; ANTÔNIO; DIONELLO, 2017), impairing the quality of the product. According to the FDA (2017) the industry plant should facilitate the regular checking for the presence of pests or infestation of them. In addition, the condition of the animal feed stored outdoors in bulk should be checked regularly to ensure adequate conditions related to the safety of the final product.

The management of the establishment should develop comprehensive control, monitoring and measures to exclude such facilities, such as: blocking possible entry points for birds, rodents and insects (using screens on doors and windows, covering holes in walls and floors and closing drains after use), using pest capture devices and cleaning to remove contaminants.

The use of cats or other animals as a method of pest exclusion is not acceptable because their presence may also lead to contamination of feed. In cases of infestation with some type of pest, disinfection with chemical products should be carried out in periods when the plant is at a standstill, followed by correct sanitation to remove residual contaminants (BRASIL, 2007).

**2.2 Contamination by microorganisms**

**2.2.1 Fungi**

Field fungi are the genus *Alternaria*, *Cladosporium, Helminthosporium a*nd *Fusarium* (WIELOGÓRSKA; MACDONALD; ELLIOT, 2016; PINOTTI *et al*., 2016).

When cereal grains and animal feed are colonized by moulds there is a significant risk of contamination with the secondary metabolites of these fungi (ATUNGULU *et al*., 2015) that may contain contaminants that impact in the animal production, such as mycotoxins, which are secondary metabolites of fungi, toxic and present in contaminated grains due to favorable environmental conditions in the period before or after harvest (BENTO *et al*., 2012; WIELOGÓRSKA; MACDONALD; ELLIOT, 2016).

The grain contained in most of the animal diets is corn (*Zea mays* L.), the cereal has a high concentration of energy and may also present structural defects in the grains such as cracks, foreign particles, impurities and breaks, which exposes it to fungus contamination, and consequently to the presence of mycotoxins that present toxicity to the animals (RUIZ *et al*., 2011; UBIALI *et al*., 2011; SAVI *et al*., 2016).

The high incidence of burned grains can be indicative of the presence of fungi, these grains being damaged during harvesting (breaks and cracks in the integument), are contaminated by the spores of the fungi that will develop in the future. The burned grains can also be derived from spikes that began their process of decomposition by the presence of fungi (STEFANELLO *et al*., 2015).

The sanitary quality of corn kernels besides compromising the nutritional value, appearance and processing (cooking, grinding, extrusion, pelletizing), can chemically modify the feed composition by the presence of substrates produced by microorganisms or degradative enzymes of the material (fermentation) as the mycotoxins (ABDOLLAHI *et al*., 2010).

Despite being a productive crop, the corn cycle faces management difficulties in storing production, supply, transportation and logistics. In these situations, the time that elapses between the storage and the use of the grains is the one that most impacts the production, because the corn is susceptible to microbiological contaminations (RODRIGUES *et al*., 2014; MEDINA *et al*., 2015).

The mycotoxins, if ingested in high amounts, can affect the health and performance of animals (BRYDEN, 2012; MURUGESAN *et al*., 2015; WIELOGÓRSKA; MACDONALD; ELLIOT, 2016), causing losses due to low feed intake, decreased performance in livestock, production and various metabolic disorders, especially in birds where the signs are subclinical in nature (BRYDEN, 2012; MURUGESAN *et al*., 2015).

The production of feed implies working with raw material of high nutritional and sanitary quality, characterized by the absence of contaminants, dirt, microorganisms, insects and pesticides (TAHIR *et al*., 2012).

It is usually the industry that defines the grain quality standard according to the type of processing, and the diet to be formulated, for example, rations for young animals are of better protein quality, free of fungi, while those made for older animals may be composed of grains of lower protein quality in a way that does not cause damage to the health and performance of animals (STRINGHINI *et al*., 2014).

The fungi of the genus *Aspergillus* are found in corn grains with high incidence in storage environments with relative humidity around 13% to 18%, are aflatoxigenic, produce aflatoxins (PINOTTI *et al*., 2016). Aflatoxin more dramatically affects the health of mammals (ruminates, pigs and dogs), causing irreversible and fatal metabolic disorders (PIEREZAN *et al*., 2010).

The mycotoxin zearalenone, in high concentrations can contaminate the carcasses of the broilers, which results in anabolic effect in humans, in the poultry production occurs reduction in the feed conversion, organ weight, fertility, drop in leucocytes, ovarian hypertrophy in females and decrease of ridge size in broilers (BRIYONES-REYES; GOMÉZ-MARTINEZ; CUERVA-ROLÓN, 2007; LIU *et al*., 1985).

The fusarium toxin is produced by a fungus that exceeds 0.025 ppm in grains, which can lead to oral lesions, generalized burning of the upper gastrointestinal tract followed by mild inflammation, in the most acute cases there are hemorrhagic areas of the skin, necrotic lesions of the mouth and throat (DIAZ; VARGAS; CORTÉS, A, 2016).

**2.2.2 Bacterium**

Good Manufacturing Practices requirements apply to raw material quality, analysis, records and provenance. A high contamination rate (46.4%) was found in rodents present in the industry's internal processing area (MORITA *et al*., 2005), which may indicate faults in the control, from the cross-contamination identified in the pest, which came from the outside as vectors of the bacterium.

Monitoring programs for *Salmonella* spp. have pro-

posed the quantification of enterobacteria or coliforms as a risk assessment tool for contamination (ANDREOLETTI *et al*., 2008).

A survey on the contamination by *Salmonella* spp. was carried out on the main ingredients available for animal nutrition, verified that the contamination was present in the different ingredients and in a varied way (SILVA; CORREIA, 2009), which shows failures in the implantation and use of GMPs (TORRES *et al*., 2011; SORIA *et al*., 2013).

According to Huss *et al*. (2018), noncompliance with the implantation of GMPs results in a risk to public health due to the presence of microorganisms in feeds that compromise animal biosafety. There is an increase in the responsibility of manufacturers to ensure the promised quality and greater competitiveness of the industry by reducing trade barriers due to the efficiency confirmed by programs such as GMPs (SCHEID, 2012).

**2.2.3 Bovine Spongiform Encephalopathy (BSE)**

The BSE became known worldwide as "mad cow disease", a disease of worldwide concern, with serious consequences for the public health and the economy of the country.

The National Program for the Prevention and Surveillance of Bovine Spongiform Encephalopathy (NPPSBSE) was instituted by NI nº 44, of September 17, 2013 (BRASIL, 2013a, 2013b). To prevent disease in Brazil, MAPA has published laws and applied restrictions throughout the production chain, from import control to the final product.

BSE is a chronic degenerative disease that affects the central nervous system of cattle, causing behavior change, staggering gait, paralysis and, invariably, death. It is caused by an infecting protein called a prone, highly resistant and infecting (PRINCE *et al*., 2003).

It is a disease transmissible to humans and, currently, there are no vaccines, or even an effective treatment for this disease, in any species (BUDKA; WILL, 2015), it is important because it is a fatal disease, difficult to diagnose, and there are no tests available to be used before the onset of clinical symptoms (WORLD HEALTH ORGANIZATION, 2012), and the diagnosis can only be confirmed after the post-mortem examination.

The main mode of transmission of classical BSE is by oral route, through the ingestion of products contaminated with the infectious prion (DUCROT *et al*., 2008). When consuming animal by-products such as bone meal or any other by-product that contains ruminant residues, the bovine animal may acquire the disease if the infecting prion is present in the product consumed (FERNÁNDEZ-BORGES *et al*., 2017).

In Brazil, two isolated cases of atypical BSE were diagnosed: in 2012, in Sertanópolis (Paraná) and in 2014, in Porto Esperidião (Mato Grosso). This fact reinforces the need for strict maintenance of the adoption of BSE surveillance and prevention measures in order to avoid the introduction and recycling of protein in the feed chain (EFSA, 2017).

The current legislation about prohibition of the production, marketing and use of any protein and fat of animal origin (including poultry litter and pig waste), except dairy products, is described in IN 8, of March 25, 2004 (BRASIL, 2004a). Its necessary follow the legislation, voiding the introduction of the contaminated protein by means of inadequate diet in the ruminant diet.

**2.3 Chemical - Mineral Contamination**

**2.3.1 Pesticides**

Various pesticides may be used in the plant only under precautions and restrictions, recommended by the labeling of each manufacturer, which will protect against contamination of feed for animals, as well as the use of chemicals on contact surfaces and packaging animal feed (FDA, 2017).

The chemicals products that are considered to be toxic must be handled by authorized and properly trained personnel for the effective and controlled use of these chemicals without causing reactions of cross-contamination by the inputs in the industry (BRASIL, 2004a).

The bait stations, or pest resistant coatings can be used to control pests, however, these materials should not serve as a potential source of contamination for animal feed (FDA, 2017), and should remain in the external areas. Toxic materials should be stored according to 21 CFR 507.19 (FDA, 2017) in specific and isolated environments of the animal.

**2.3.2 Heavy metals**

The permitted limits for metal residues in feed products are described in MAPA Decree 55.871 of March 26, 1965 (BRASIL, 1965). That refers to the regulations governing the use of feed additives, as amended by Decree No. 691 of March 13, 1962 (BRASIL, 1965).

Heavy metals are defined as those accumulating in the soil and in the body of animals and humans, favoring cross-contamination, either by excess fertilizers, by the use of improper lubricants, the use of unauthorized hygiene materials, and even by dissemination through pests (BRASIL, 2016). High toxicity metals are present in various fertilizers, such as Arsenic (As), Cadmium (Cd), Lead (Pb), Mercury (Hg) and Chromium (Cr), and the dosage allowed for application varies according to the each country (BRASIL, 2004b).

Metals known as micronutrients, such as Cu, Zn, Mn, and Fe, are required in small concentrations in the body. They are absorbed and metabolized, however, in high concentrations they become toxic and may be lethal to fish, birds and humans (SAFIUR RAHMANB *et al*., 2019).

The increasing accumulation and severe toxicity of heavy metals has gradually increased, causing irreversible damage to the environment. One of the most commonly found contaminants in the environment is lead (Pb), which has a toxic effect on all body systems and no physiological function in the body (MOREIRA; MOREIRA, 2004).

**2.3.3 Dioxins - Furans (PCDs and PCBs)**

Dioxins, polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDF) are tricyclic aromatic compounds, that have ether function and are generally byproducts of the synthesis of herbicides, disinfectants and others. These make up a highly toxic group of compounds that persist contaminating the environment (ASSUNÇÃO; PESQUERO, 1999).

The most acute toxicity is identified in 2,3,7,8-tet-

rachlorodibenzopio dioxin (2,3,7,8-TCDD), which has negative effects for different species. In the case of dioxins and PCBs in the form of dioxin, the World Health Organization (WHO) has established new acceptable levels in 2005, and issued a report "Results of the surveillance of the levels of dioxin in foodstuffs and feed animals." (EFSA, 2010).

In the US, the largest source of dioxin comes from fat-soluble feed, which accumulates in the food chain and is found in meat, milk and its derivatives (HUWE, 2002). Some countries have included polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCBs) unintentionally formed as persistent organic pollutants, some countries have included polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCBs) unintentionally formed as persistent organic pollutants, taking assumed control responsibility to minimize the emission of these pollutants into the environment. (DRAFT, 2004; LALLAS, 2001).

Due to the negative effect that the pollutants can cause, the management methods and the application of the herbicides in the cultivation of seeds that will be used in the feed industry become important, preventing the origin of new sources of contamination.

**2.4 Hygiene material**

As cleaning and sanitation measures of facilities, the Standard Operating Procedures of this modality should have information related to operations, to the products used with proper concentration, active principle and time of action (ROEGER; TAVARES, 2018; SWAINSON, 2019).

The cleaning material used in the production line must be stored in a separate place and with restricted access to those responsible for the hygiene of the industry. The chemicals products can be used directly on the equipment in order to sanitize and sanitize only during periods of production stoppage, following the dosage and application recommendations in order to avoid any residual presence for cross-contamination (BRASIL, 2007).

All the equipments and utensils in raw material handling environments that may come in contact with the ingredients must not be toxic, odorless, tasteless, waterproof, corrosion resistant and capable of withstanding repeated cleaning and disinfection operations (BRASIL, 2007).

**2.6 Quality Control**

**2.6.1 Good Manufacturing Practices (GMPs)**

According to the US Department of Agriculture's (USDA) Feed and Drug Administration (FDA), the Good Manufacturing Practices define the requirements for the manufacture of animal feed, guide the industry regarding the management of the establishment, the importance in considering factors such as the types of animal feed, how the feed is identified, the storage location and the practices used to load and unload the feed, procedures necessary to avoid cross-contamination (FDA, 2017).

The objective of NI 4/2007 is to define the basic hygiene and GMP procedures for manufactured and industrialized feeds for the consumption of animals, thus, it applies to any manufacturer or fractionators of animal products (BLEOTU *et al*., 2018; BRASIL, 2007; SCHEID, 2012).

With regard to obtaining quality products in the feed manufacturing process, attention is required from the design of the plant, involving its construction, selection and installation of its equipment, to the rigid choice of ingredients suppliers, establishment of feed formulations, including the correct weighing, milking characteristics, premixing of vitamin concentrates and supplements, mixing of feeds, supervision of ready to eat rations, storage, maintenance and cleaning of equipment of the industry and, finally, the general hygiene of the industry and employees (CORADI; LACERDA FILHO; MELO, 2009).

Effective implementation of management tools such as GMPs throughout the production chain is an important measure to maintain control and ensure the quality of feed products. In this implementation, the use of technologies and qualified professionals are the main determinants of industry results (BRASIL, 2007).

GMPs do not only involve monitoring the manufacturing process of the products, but include, among other procedures, the participation of the people, the personal cleanliness of the employees, the isolation of sectors of the industry, everything to ensure the quality of the final product (BRASIL, 2007), in order to standardize procedures, reducing costs with losses and rework. Therefore, it is necessary that each company has its own manual according to its reality.

**2.6.2 Standard Operating Procedures (SOPs)**

The definition of SOP is understood as the objective description of instructions, techniques and routine operations to be used by manufacturers of animal feed products, aiming at the protection and quality (AUNG; CHANG, 2014). They must be clearly and accurately described in the Operational Manual and all operations must be carried out in accordance with it (SCHEID, 2012). They must be reviewed on the spot, at least once a year, in order to verify that they are meeting their objective, being adjusted whenever necessary and should be changed whenever there is any change in the company's operational procedure (BLEOTU *et al*., 2018; SCHEID, 2012).

With regard to SOPs for prevention of cross-contamination, it should identify possible sites and forms of occurrence by applying the mandatory SOP principles. For example, integrated pest management should utilize all preventive and control measures in the establishment in relation to insects and small rodents (MATTHEWS, 2017; VILA-DONAT *et al*., 2018).

The manufacturing process of different products follows a sequence of rational production as a way to avoid cross contamination, observing the category and animal species to which the product is destined. It is observed in its composition the addition of products of animal origin, antibiotics, additives or other chemical compounds. Taking into account the order of manufacture according to the sensitivity of animal to certain ingredient of the feed.

In this sense, equine rations must be manufactured before cattle are more sensitive animals, some ingredients used in cattle feed may be harmful to their health (BRASIL, 2004a), therefore requires greater care in the hygiene of the production line.

The SOP referring to the hygiene and health of employees, workers in the feed industry must specify, all the

procedures regarding the use and hygiene, the uniforms, hygienic habits, state of health and specific training. The use of personal protective equipment (PPE) in the industry is indispensable, and in some sectors it is mandatory to use mouth and nose masks, avoiding the spread of diseases (BRASIL, 2007).

An individual should be able to consistently perform assigned tasks in a manner that protects feed of animal origin from contamination or tampering, recognizing the presence of undesirable substances in the raw material, uniforms, facilities, equipment and utensils, with training and safety to take risk elimination actions and prevent cross contamination (FDA, 2017).

**2.6.3 The water**

The water has specific SOP that treats the potability and hygienization of the reservoir, specifies the microbiological and physicochemical standard, including all steps: capture, treatment, storage, distribution, collection points, analysis, monitoring, corrective actions, verification and records. It is essential to maintain the frequency of the analysis, monitoring and verification of tank cleaning (ROEGER; TAVARES, 2018).

The use of non potable water is permitted when it is intended for the production of steam, fire control and other purposes that do not maintain direct contact with the products. All water used for formulation, cleaning of facilities and equipment and personal hygiene should be potable. Drinking water is defined as that which is free of pathogenic microorganisms (OMS, 2009) and under conditions of consumption.

**2.6.4 Hazard analysis and critical control points (HACCP)**

The production of feed in animal feed processing industries is considered a complex process and during its elaboration may have numerous variables which may impair the quality and consequently the performance of the animals (CORADI; LACERDA FILHO; MELO, 2009). According to SINDIRAÇÕES (2002), these variables are called critical control point, that is, it is the stage of the process in which the control must be applied to prevent or eliminate a hazard or to reduce them to acceptable levels.

The HACCP is considered a primordial tool for the whole system, especially for the determination of the points where the identification of the hazards in the control is most critical. Dangers can be chemical (pesticides, disinfectants), physical (dust, foreign bodies) and biological (microorganisms) (BRASIL, 2007; RIBEIRO-FURTINI; ABREU, 2006).

HACCP is considered to be the main handbook of good practice, used as a scientific health support by North American establishments to prevent contamination by introducing pathogens into the plant, into the environment, reducing microbiological risks, and ensuring that the establishment's interventions have achieved the effect (FDA, 2017).

From this perspective, the HACCP system is an instrument of preventive actions for the detection of hazards and critical control points related to the safety and quality of the feed chain. It is a system for preventing the occurrence of problems, ensuring that the controls are applied efficiently at each stage of the feed production system. The system is applicable in all stages of feed manufacturing, from industry to trade and consumption by animals (ALVES; BIAGI, 2015).

The application of HACCP in the feed industry entails an increase in credibility, not only related to product safety, but also due to the certainty of compliance with the requirements of the inspections. The lack of trained personnel and the precarious infrastructure conditions are the main difficulties faced in the implementation of this product quality management tool (DEN HARTOG, 2003).

The use of the HACCP system generates a quality product for the animals, highlights the companies at a competitive level, increases the possibilities of expansion in national and international markets, and results in the minimization of losses of raw materials, packaging and products, defining as a goal that safe products will be the result of safe ingredients and processes (COUTO, 2008).

**2.7 Preventive measures**

In order to prevent the contamination of products intended for animal feed, all processing areas, equipment and utensils must be cleaned as often as necessary and disinfected where circumstances are require. The establishment must ensure its cleaning and disinfection by means of a specific program, determined in the Manual of Self Controls. Employees should be trained to perform cleaning procedures and be fully aware of the hazards and risks of contamination.

The application of GMPs should combat and minimize microbiological, physical and chemical contamination. Investing in training the people involved in the activities, enabling them to execute the SOPs, in order to obtain clear processes, free of defects and contamination, will result in safe products and services (ALVES; BIAGI, 2015).

The use of GMPs in the feed industry is an indisputable methodology, which consists of establishing norms, standardizing and defining procedures and methods that regulate all the manufacturing activities of a product and, or the execution of a service, to make employees aware of appropriate hygiene and feed handling practices, to reduce contamination levels and to ensure the safety and quality of products (VARGAS; RASZI, 2012).

Studies of the quantification of indicator microorganisms, such as enterobacteria and total coliforms, have been proposed to verify the effectiveness of decontamination processes, to evaluate the hygienic sanitary conditions of the production lines of feed factories and to estimate the risk of contamination by pathogens (JONES; RICHARDSON, 2004; VELDMAN *et al*., 1995).

With regard to waste disposal, the FDA recommends that waste be transported, stored and disposed of in a manner that avoids contamination of feed, feed materials or packaging materials, feed water and soil surfaces, avoid accumulation to attract or harbor pests or serve as breeding grounds for them (FDA, 2017).

Measures to prevent cross contamination must be taken in order to avoid contamination by direct and indirect contact in all stages of the process and production flow, considering facilities, equipment, personnel, utensils, uniforms and packaging. A fixed sequence should be established for the manufacturing process of the different products taking into account the use of ingredients of animal origin, additives and veterinary products according to the different species, and it is suggested to use different production lines for

ruminants and monogastrics due to the possibility of contamination of the inputs used in the production, respecting the legislation that prevents the consumption of products of animal origin by ruminants (BRASIL, 2013b). In this sense, traceability is mandatory for all feed handling companies.

Although several studies have cited ingredients as the main culprit for the introduction of contaminants in the processing line of factories, other factors such as dust, rodent presence, moisture and stocking time have been considered capable of influencing the safety of a feed batch (JONES, 2002; COMA, 2003; RICHARDSON, 2008).

The adoption of HACCP programs and, GMPs during the elaboration of diets in feed factories, are essential strategies to minimize the risk of cross contamination (PRIMM, 1998; PETRI, 2002).

Considering the sequencing of production as required by the legislation, the establishment should employ procedures to clean the equipment that warranty the safety of the product. The material used in this operation must be identified and stored in its own place. These procedures should be validated and checked periodically, in cases where there is a high risk of harm to feed products linked to cross contamination, and if the use of cleaning methods is considered inefficient, separate production, transport, storage and delivery lines for monogastrics and ruminants.

## 3 Conclusion

It is concluded that the main sources of cross contamination are present both internally and externally to the plant, leading to an inflow and outflow, the most frequently observed contamination points were the presence of pests, the receipt of contaminated material and inputs, and the accumulation of dirt on the equipment due to dust and moisture.

The best way to avoid cross contamination is prevention in all feed manufacturing processes, in order to minimize the presence of external and internal contaminants. An effective and efficient control of the presence of cross contamination is obtained from the reliable execution of all the control programs, since the production of the inputs, transportation, storage, industrialization until the stocking of products ready for trade. When all monitoring, verification and correction, immediate and continuous, action plans are followed, the occurrence of contamination can be anticipated to minimize losses and costs.

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