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# ANALYSIS OF POTENTIAL RISKS IN FEED PRODUCTION AS AN INTEGRAL PART OF FOOD CHAIN

**Olivera ĐURAGIĆ, Ivana ČABARKAPA, Radmilo ČOLOVIĆ**

University of Novi Sad, Institute of Food Technology, Bulevar Cara Lazara 1, Novi Sad, Serbia

Corresponding author email: olivera.djuragic@fins.uns.ac.rs

***Abstract***

*In order to ensure food safety, it is necessary to consider all aspects of the agri-food chain, from the primary agricultural production, including animal feed production to consumer supply, since each of these links in the chain may affect the safety of final products. In the feed production, each unit operation can contribute to the quality and safety risk of feed products. This paper isfocused on the identification and monitoring of critical points in the technological process of feed production, which are usually not covered by the HACCP quality assurance systems. Results of homogeneity and carry over in the critical control points showed that about 25 % of tested feed mills have a problem with residues in the process, which could be potential risk for cross contamination. In the three feed mills level of carry-over was slightly above limits, which may result in the creation of conditions for contamination of the subsequent batch. Additionally, results of the monitoring of Salmonella spp., Escherichia coli, and Staphylococcus aureus presence on the surfaces in feed millsshowed that feed factory environment might also represent one of the potential sources of final product contamination. Results showed that 7% of samples were positive to Salmonella sp. and even 50% of samples were positive on other bacterial contaminants. Introducing adequate control system will contribute to the identification of microbiological contaminants at all stages of production chain (feed-animal-food-human chain), as well on their prevention, which will have a direct impact on food safety and animal and human health.*

***Key words:*** *feed, safety, risk, food chain, Salmonella.*

## INTRODUCTION

Food is considered as a basic human need and the food supply chain cannot be a part of the free market. Food safety is always in a focus of the public, non-governmental organizations, professional associations, international trading partners and international trade organizations. It is necessary to ensure that all stake holdersraise a vote for open and transparent discussion on food legislation and to take steps to inform the public about possible health risk (Sredanovic et al., 2012).

In order to ensure food safety, it is necessary to consider all aspects of the agri-food chain, from the primary agricultural production, including animal feed production to consumer supply, since each of these links in the chain may affect the safety of food. Nowadays it is generally accepted that the animal feed production is very important link in the production of safe food of animal origin. Food chain organization includes primary agricultural producers and feed producers, food processors, operators and contractors in transportation and storage, retail sales and provision of services related to food (together with organizations related to this sector such as manufacturers of vehicles, packaging material, cleaning, and ingredients) (Ryan, 2017).

Feed production is an important link of the food chain which should provide sustainable, safe and valuable food products. Feed producers have to ensure systematic control in all stages of production, processing and distribution in accordance with EU legislation as well as with good manufacturing practice and other quality systems (HACCP, GMP+, etc.).

In the feed production, each unit operation can contribute to the quality and safety risk of feed products. Equipment like transporters, dividers, extractors, cells and bins, mills, scales, mixers, equipment for hydrothermal and mechanical treatments (conditioners, pellet mills, extruders, expanders), coolers, dryers, could be considered as a critical points in the production process from the safety aspect. Potential contamination places can be formed by

inadequate construction of equipment, malfunction, damage or unprofessional conduction of the process (Verstraete, 2013).

It is necessary to achieve working accuracy of the whole animal feed production process by risk reduction and avoiding of accumulation of the raw materials and products in critical points of process line. Working accuracy involves maintaining the stability of the dry mixture and avoiding variations in concentration of ingredients and losses due to the retention of the ingredients in whole process line (not only in the mixer).

Therefore, the criteria for proving the working accuracy includes three components:

- concentration of the additive in the final product in relation to the declared level;
- homogeneity of the additives in the final mixure;
- level of carry over and possible contamination of the subsequent batch (Djuragic et al., 2007; Vukmirovic et al., 2010).

Taking into account the allowed tolerances, experimentally determined concentration must be within ± 10% of the declared concentration and not to exceed the permissible coefficient of variation for homogeneity of the mixture (Djuragic et al., 2009).

A deviation of the uniform distribution can have a negative effect on animal health. For example, excessive doses can be fatal to the animals or can leave residues in meat, milk and eggs and throughout excreta can cause environmental pollution.

Carry over is the form of contamination which occurs when a substance is transferred from one batch to another. The undesired substances, such as high concentrations of drugs used in a medicated feed or microbiologically contaminated crusts and residues, should be prevented to contaminate the subsequent batch in a production line. Carry over can occur in a single piece of equipment, or as a result of a combination of residues in the whole production system. As soon as operators determine the source of carry over, corrective measures can be taken (O'Mahony, 2014).

Apart from the above mentioned, the highest microbiological risk in animal feed represents contamination with bacteria from the genus *Salmonella* spp. With respect to feed safety, preventing *Salmonella* spp. to enter the agri-food chain have a great importance in minimizing safety risk, since their presence in animal feed is associated with a high risk of animal infection and, consequently throughout animal products, human infections. Therefore it is considered as a major microbial hazard in animal feed (Jones, 2011). The link between *Salmonella* in animal feed and human salmonellosis has been well known for many years.

It is widely recognized that, in response to different environmental conditions, bacteria such as *Salmonella* spp. have developed a variety of strategies to adapt and survive. The formation of multicellular communities, known as biofilms, is one such strategy, which is generally associated with the survival and persistence in different environmental conditions (de la Fuente-Núñez et al., 2013; Hall-Stoodley et al., 2004). Contamination of feed production plants with biofilm producing strains usually occurs through contaminated raw material. Contamination may occur at any point from the field to the final product, by aerosol and the human factor. As potential sites for biofilm development, the most often identified are: receiving bin for raw materials, walls, ceilings, drains, pipes, ventilation systems, working area, conveyor belts, the outer and inner surface of processing equipment (especially in blind spots and pockets), cavities, joints, cracks and areas prone to condensation.

Although the feed production is mainly based on the "dry food" production, which considerably limits the growth and development of microorganisms, due to temperature variations within the production process, in certain areas condensation may occur which can provide sufficient humidity to promote the development of bacterial biofilms, including *Salmonella*. Studies have shown that microorganisms, especially *Salmonella* spp. overcome the temperature and humidity fluctuation in the equipment of the feed industry by entering into viable but nonculturable (VBNC) stage (Habimana et al., 2010; Habimana et al., 2014; Møretrø et al., 2009). In northern Serbia, in the region of AP Vojvodina, analysis of the presence of *Salmonella* spp. in samples of animal feed in 2014 and 2015, which were delivered to the Scientific Veterinary Institute in Novi Sad, revealed that *Salmonella* spp. was detected in 146 samples. In 2014, 101 (19.71%)

out of a total of 1952 analyzed samples, were positive to this bacteria. In the reduction in the number of positive samples occurred since. In 2015 a total of 1612 samples were analyzed, from which 45 (2.7%) were positive to the presence of *Salmonella*. These findings confirm the fact that the feed and raw materials may represent a significant source of contamination with *Salmonella*, and place where these severe contaminants can enter the agri-food chain. In favor of the topic, data published by the EFSA (European Food Safety Authority) showed that for European countries (EFSA state) the overall level of *Salmonella*-positive units in animal- and vegetable-derived feed material in 2015 was 5.13%. In 2014 and 2013, prevalence of 3.8% and 1.4% was reported, respectively, and thus, a slight increase in prevalence of *Salmonella*-positive units in feed material was observed in 2015 (EFSA, 2016).

EFSA also reported that among different matrices, the most commonly tested feed material was soya (bean)-derived feed material with 3,404 samples tested and a mean *Salmonella* prevalence of 3.7%. Also, high prevalence was reported for meat meal (290 tested, 16.7% positives). In the finished feed for animals (compound feedstuffs), the prevalence of *Salmonella*-positive units in 2015 was low to very low for all animal species: 1.20% of 2,248 tested samples for cattle, 0.51% of 2,754 tested samples for pigs and 0.67% of 7,961 tested samples for poultry (EFSA, 2016).

Next to the raw materials, feed factory environment might also represent one of the potential sources of final product contamination. *Salmonella* spp. can enter the final product by contact with contaminated processing equipment. Therefore, the aim of this study was to analyze potential risks for the safety in animal feed production and agri-food chain, such as unacceptable working accuracy in the feed mills and bacterial contaminants presence in feed samples and on the surface of the equipment.

## MATERIALS AND METHODS

Research was focused on the identification and monitoring of critical points of the technological process of feed production, usually not covered by the HACCP quality assurance systems. Those points were identified as potentially critical points in the technological process as a risk for formation of a heterogeneous mixture, the cross-contamination and microbial contamination.

Following safety parameters were tested:

- working accuracy of the whole feed manufacturing process;
- level of carry over and cross-contamination;
- microbiological analysis of the swabs taken from the technological equipment

Tests were carried out at feed plants within the territory of Province of Vojvodina. Samples were taken at different points in process (potentially critical zones) depending on the production process. Samples were taken from mixers, hopper, conveyors, chain conveyors, screw conveyors and surge bins as well as during packaging into bags. Determination of homogeneity and carry over level was done by Microtracer® method (Micro Tracers, Inc., San Francisco, CA 94124) as a physical method of homogeneity testing. A sufficient amount of iron filings (Microtracer RF, blue), colored with a soluble die, is added to the mix in mixing ratio 1:10.000 (100 g/t).After main batch with Microtracer, two rinsing batches for determination of carry over level were performed and samples were taken from the same points.

Microbiological analysis of the working surfaces was performed in accordance with the guide for taking swabs from surface area (ISO standard 18593: 2004). Swabs were taken on the surfaces that have been flagged as potentially critical locations in the process, from the surface of 10x10 cm, after they were converted in number of microorganisms per unit area (1 $cm^2$).

## RESULTS AND DISCUSSIONS

Results of homogeneity testing performed in various feed mills in order to check homogeneity during the whole production process are shown in the Figure 1. It has been shown that in some feed mills homogeneity which was achieved in mixer is slightly changed in the downstream equipment depending on the sampling point. Dry mixtures manipulation within some equipment, such as elevators, long transporting paths, loading bins or chain

conveyers, had negative influence on mixture stability. In considerable number of feed mills coefficient of variation for homogeneity of mixture was lower than 10%, which is acceptable from the quality and safety point of view. However, results of homogeneity in the three feed mills (feed mills no. 5, 9, and 10) it can be seen that coefficient of variation was higher than 10% from the beginning of process (from the mixer) and through the whole production line. Such results are indicating that in these mills level of some ingredients in complete mixtures might exceed prescript values, which impose a potential risk for negative effect on an animal health. Furthermore, results of homogeneity also in the line with the carry over results (Table 1).

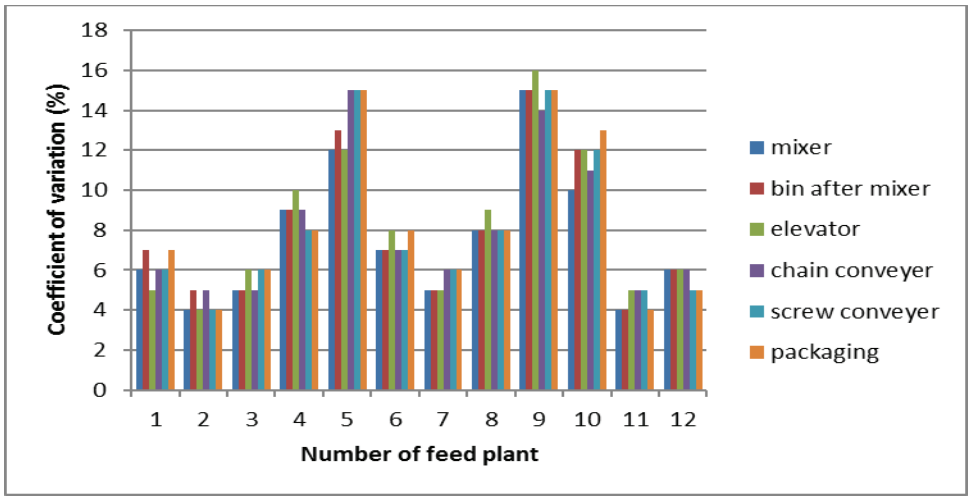


Figure 1. Homogeneity of production line in different feed mills

Table 1 shows the results of the level of carry over in the tested feed mills. When compare the results from both technological tests an increased level of carry-over was detected in places where there was no satisfactory homogeneity. Unlike the homogeneity, according to Serbian legislation, there is no declared level for carry over in feed production.

Based on European research and experience in some of the EU countries, it is considered that the level of carry over should not exceed 4% in the production of compound feed and up to 1% in premix production.

As was the case with the homogeneity tests, in the feed mills no. 5, 9, and 10, level of carry-over was slightly above those limits, which may result in the creation of conditions for contamination of the subsequent batch.

As was already pointed out, depending on the environmental conditions (temperature, humidity), feed mills could be suspected to microbial contamination which one of the major threats that can negatively affect food chain security.

Table 1. Results of carry over tests in feed mills

| Place of sampling | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Level of carry over, % | | | | | | | | | | | |
| Mixer | 1.2 | 0.1 | 3.4 | 0.8 | 3.9 | 0. 9 | 1.4 | 0 | 3.4 | 3.9 | 1.3 | 0.5 |
| Bin after mixer | 1.1 | 0.5 | 3.0 | 0.7 | 3.6 | 0.6 | 1.1 | 0.5 | 3.3 | 4.5 | 1.0 | 0.9 |
| Elevator | 2.3 | 1.1 | 2.4 | 0.8 | 3.9 | - | 0.8 | 0.6 | 4.1 | 4.4 | 1.1 | 1.0 |
| Chain conveyer | - | - | 2.4 | - | 4.1 | - | - | - | - | 2.9 | - | - |
| Screw conveyer | 1.2 | 0.9 | - | - | - | 0.5 | 0.9 | - | - | - | - | - |
| Packaging | 1.4 | 1.1 | 3.8 | 2.0 | 4.3 | 0.9 | 1.5 | 0.1 | 5.2 | 4.9 | 1.2 | 0.8 |
| **Mean value** | 1.44 | 0.74 | 3.0 | 1.07 | **3.96** | 0.66 | 1.14 | 0.3 | **4.0** | **4.12** | 1.15 | 0.8 |

Results of monitoring environmental hygiene in feed factory environments are presented in Table 2. Out of 100 analyzed samples collected from various parts of feed factories, 10 were positive to presence of *E. coli*, and 7 to *Salmonella* spp. Presence of *S. aureus* was not

identified. *Enterobacteriaceae* in the amount of >100 cfu/cm$^2$ were detected in 23 analyzed samples. Therefore, the monitoring of microorganisms contamination, especially the *Salmonella* spp. on the surfaces within feed factories, confirmed that the environment might also represent one of the potential sources of final product contamination.

The presence of other types of microorganisms, other than *Salmonella* spp., is important in terms of their ability to form biofilms.

Research conducted by Davies and Wray (1997) is in line with the results of this study. These researchers also suggested a link between *Salmonella* contamination within feed mills and management or environment.

In Western Balkan region, a permanent monitoring of feed factory environments and bacterial contamination of animal feed is still not adequately integrated into the programs for monitoring microbial contamination of products of animal origin for human consumption and the occurrence of human alimentary infections.

Introducing adequate control system like in some Scandinavian countries will contribute to the identification of microbiological contaminants at all stages of production chain (feed-animal-food-human chain), as well on their prevention, which will have a direct impact on food safety and public health.

Table 2. Monitoring environmental hygiene in feed factory environments

| No. | Surface area | Number of tested sample | *Enterobacteriaceae >100* | *E. coli* (+/-) | *S. aureus* (+/-) | *Salmonella* (+/-) |
|---|---|---|---|---|---|---|
| | | | Number of positive sample according to criteria | | | |
| 1. | Elevator for raw materials | 5 | 3 | 1 | 0 | 1 |
| 2. | Screw transporter that follows elevator | 5 | 3 | 1 | 0 | 0 |
| 3. | Elevator between scale and mixer | 5 | 3 | 2 | 0 | 0 |
| 4. | Mixer | 5 | 4 | 3 | 0 | 3 |
| 5. | Receiving hopper below mixer | 5 | 1 | 0 | 0 | 0 |
| 6. | Elevator between mixer | 5 | 2 | 2 | 0 | 0 |
| 7. | Surge bin | 5 | 2 | 0 | 0 | 1 |
| 8. | Conditioner before pellet press | 5 | 2 | 0 | 0 | 1 |
| 9. | Pellet press | 5 | 0 | 0 | 0 | 0 |
| 10. | Cooler | 5 | 3 | 1 | 0 | 1 |
| Σ | | 100 | 23 | 10 | 0 | **7** |

## CONCLUSIONS

Based on the obtained results, it can be concluded that in the 25% feed mills homogeneity in the process was not satisfactory, since coefficient of variation of series of samples, was higher than 10%. In all of feed mills with high coefficient of variation, homogeneity nor been achieved in the mixer, neither was improved during downstream processing.

Insufficient homogeneity was prerequisite for carry over in the subsequent batches and potential risk for animal health.

Results of microbiological swabs have shown presence of some bacterial species in the feed mills, 7% of samples were positive on *Salmonella* spp. while totally 50% of tested samples were positive on other *Enterobacteriaceae* including *E. coli.* Presence of these contaminants on the equipment surfaces might cause risk for the feed products contamination, and throughout the animal products, potential risk for the contamination of food.

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