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Biogenic Amines in Meat Meal

What are biogenic amines?

Biogenic amines (metabolites) are known to occur in all living organisms. The universal occurrence of these metabolites in all cells implies that they have an important biological function. Although they have been identified as necessary for growth, biogenic amines have also been shown to be toxic. Recent suggestions imply a possible role in carcigenosis, the growth of cancerous cells.

Biogenic amines occur at low concentrations in all cells and are generally formed as by-products of the decarboxylation of amino acids. In aged, fermented or putrefied food and meat products where microbial growth has occurred, the concentrations are often found to be much higher. Any free amino acids in spoiled products can be broken down by means of deamination (the production of ammonia) or decarboxylation by microbial decarboxylase enzymes (the production of biogenic amines).

This latter reaction is important to renderers of animal by-products. An increase in the biogenic amine content of any meat product, especially meat meals, indicates a decrease in protein quality through the loss of amino acids and the increase in the concentration of potentially toxic compounds. Both of these outcomes are undesirable in animal nutrition.

Occurrence of biogenic amines

As would be expected from the universal occurrence of biogenic amines in cells, these compounds are found in all foods. Amines are grouped by their molecular structure. The most important biogenic amines that occur in foods are the heterocyclic amines, histamine and tryptamine; the aromatic amines such as tyramine and phenylethylamine; the diamines, putrescine and cadaverine; and the polyamines, spermine and spermidine. Most studies of biogenic amine concentrations in food have focused on fish and cheeses because of the association of biogenic amine (especially histamine) poisoning with these foods. A limit of 100 milligrams of histamine per kilogram of product has been set by the Australia New Zealand Food Authority (ANZFA) for foods destined for human consumption in Australia.

Several quantitative methods are available for the determination of biogenic amine concentrations, with those using very sensitive High Pressure Liquid Chromatography the current methods of choice. Levels of histamine up to 5,000 mg/kg have been recorded in fish, and fish products. A recent survey of fish, and fish products, found that about 15% of samples exceeded the 100 mg/kg limit. Analysis of animal protein meals in the same survey found that the highest levels of histamine, putrescine and cadaverine occurred in fish meal.

Biological functions of biogenic amines

In addition to being precursors for the synthesis of hormones, nucleic acids, neuro-transmitters and proteins, amines are important food aroma components.

They are also precursors for the formation of carcinogenic N-nitroso compounds. The diamines putrescine and cadaverine, and the polyamines spermine and spermidine have a role in the regulation of nucleic acid synthesis, protein synthesis and membrane function. As a result they are important in cell proliferation. For this reason the diamines and polyamines are extensively studied in connection with cancer.

Where cases of food toxicity due to these types of compounds is found to occur, it is usually due to the monoamines such as histamine, tyramine, phenylethylamine and tryptamine. Some amines, especially diamines and polyamines, have potential as indicators of food spoilage.

Biologically active amines are classified by their function. Some amines act on the vascular (blood distribution) system. These include blood-pressure-increasing

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tyramine, tryptamine, phenylethylamine and isoamylamine; and blood-pressure-reducing histamine and serotonine. Others are psychoactive and act on the nervous system including norepinephrine, serotonine and dopamine.

Feeding studies with diets including added biogenic amines on calves, pigs and chickens have given variable results. In some instances the inclusion of biogenic amines has been shown to enhance growth, and in others to be toxic. The reasons for this variation may be due to the dietary concentration fed, the animal's metabolic capacity, its physiological state, its toxicity threshold or the interactions that occur between different biogenic amines. The relative importance of these factors in determining the outcome of ingestion of biogenic amines is poorly understood.

It is known, however, that the situation regarding the ingestion of amines is extremely complex, as indicated by the need for animals to externally source polyamines. These compounds are preferentially directed to tissues and organs that have been stimulated to grow by metabolic signals within the animal. They must be sourced by the animal through food as they cannot be sourced internally through biosynthesis.

Spoilage and biogenic amine formation

Only very small concentrations of biogenic amines occur in fresh foods. It has been proposed that increases in the concentration of these compounds may indicate spoilage of a food—especially fish, dairy products, meat and wine. Different biogenic amines have been proposed as the indicators of spoilage in different food products. In minced beef, significant correlations have been found between the presence, and concentration, of putrescine, cadaverine and spermidine and the total microbiological count in the product. However the relationship to spoilage is not straightforward as the composition of the total microbial population is not constant and the particular bacteria present may not produce the indicator amine.

Storage conditions and processing will influence the quantity and profile of biogenic amines produced in a food product. Amine production is determined by:

- the composition of the bacterial population, in particular the presence of decarboxylase-positive bacteria;
- the presence of a suitable inducer, or catalyst, of decarboxylation;
- the availability of suitable free amino acids as substrates to produce biogenic amines;
- the composition of the raw material;
- the presence of environmental conditions (especially temperature, pH and water activity) that favour microbial growth.

Control of these factors during processing and storage should reduce the level of biogenic amines in a finished food product. The development of suitable strategies to control these conditions during rendering will reduce the formation of biogenic amines in meat meal.

Biogenic amines in Australian rendered product

A comprehensive study has been conducted on the range of rendering processes carried out in Australia and the levels of the biogenic amines putrescine, cadaverine and histamine produced in product from these various processes. Eighty-five samples from plants within the following process categories were analysed.

- Batch dry rendering — 47 samples
- Continuous dry rendering — 27 samples
- Digester wet rendering — 3 samples
- Low-temperature wet rendering — 4 samples

Four other samples were received from plants that had either an alternate process or gave insufficient information to determine the nature of the process.

From the results of the analysis of these samples and the detailed information on the processes provided by the renderers, a wide range of processing variables and biogenic amine contents, and profiles, could be determined. From this data a number of observations can be made that confirm the strategies required to minimise the level of biogenic amines in meat meals.

1. The longer the time delay between the generation of raw materials at an abattoir, or boning room, and the processing of these materials at the rendering plant, the greater the level of biogenic amine in the finished product.
2. If the delay occurs after particle size reduction occurs, the increase in biogenic amines will be greater than if the delay occurs before size reduction.
3. Gut material and offals show increases in biogenic amines over a shorter storage period than boning room materials.
4. The higher the ambient storage temperature of the raw material prior to rendering, the higher the concentration of biogenic amines produced.
5. Holding raw materials for an extended period under refrigerated conditions (4–8°C) prevented any significant increase in the level of biogenic amines.
6. Heating product to a temperature adequate to destroy most bacteria and inactivate enzymes in the raw material prevented any significant further increase in the level of biogenic amines.
7. Total biogenic amine concentrations in the meat-meal samples ranged from 20 mg/kg to in excess of 800 mg/kg. Cadaverine was generally of the highest concentration followed by putrescine and histamine.

Dry batch rendering and low-temperature wet rendering produced similar levels of biogenic amines in their resultant meals with 75% of samples in each category having biogenic amine levels below 100 mg/kg. Digester wet rendering produced slightly higher levels with about 65% of samples below the 100 mg/kg concentration. Continuous batch

rendering samples showed a significantly higher level of biogenic amines with only 37% of samples below 100 mg/kg.

The process type and the process temperature may not necessarily be the determinant of the level of biogenic amines. The condition of raw materials fed to the process and the time for the process to heat materials sufficiently to stop bacterial and enzymic activity are more likely to be the influencing factors.

Strategies for minimising biogenic amines

The following recommendations are made to minimise the concentration of biogenic amines in finished meat meals.

- Process raw material as quickly as possible before bacterial action can occur to any significant extent.
- Where delays in raw material handling cannot be avoided, hold product at as low a temperature as possible. Where materials are from a cold environment such as a boning room, materials should be keep cold for as long as possible.
- Where delays cannot be avoided, the particle size should not be reduced until as late as possible prior to processing.
- Where delays cannot be avoided, gut and boning room material should be kept separate as late as possible prior to processing. This will minimise the effect on the boning room material that has a lower bacterial population and is more stable to bacterial action than gut material.
- Where delays cannot be avoided, heating raw materials to 80°C will prevent bacterial activity and minimise the increase in biogenic amines.

Biogenic amines are produced as a result of specific bacterial activity. Avoiding conditions that promote bacterial activity will limit the opportunities for increases in biogenic amines.

Further reading

This information is a summary of information prepared for Meat and Livestock Australia by the University of Sydney and Victorian State Chemistry Laboratory. Details of the Australian industry review, and sample analysis, have been published as a report entitled Biogenic amines in meat meal (July 1999). This report includes an extensive bibliography of references relating to biogenic amines in animal and plant materials and their effect on animal production. This report is available from Meat and Livestock Australia (Project Code USO21).

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