Feed microscopy in feed and pet food

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For farm animals to manifest their genetic production potential, it is important that they receive optimally balanced diets. Well-balanced foods also are required by all the different classes and categories of pets to meet their daily needs, be it for the working dog or for the whole-day-couch-sleeping cat.

Feed/food manufacturers want to sell the best products, and they strive to produce high-quality foods. Balanced foods consist of mixtures of various food raw materials, and the cliché that the quality of a food cannot be better than that of its ingredients still holds true.

Although feed quality may be affected by numerous factors, the purity of ingredients is the primary area where feed microscopy can make a difference.

While feed manufacturers usually consider and evaluate all the above-mentioned aspects, the purity of ingredients is often neglected. No quality-control program is complete if it does not include tests to verify the purity of food raw materials. Adulteration of food ingredients does occur, and the inclusion of adulterated ingredients can have a marked effect on feed and food quality.

What is adulteration?

Feed adulteration may be defined as the intentional, but illegal, modification of a pure feed raw material by the addition of any other ingredient, and its sale under the pretext of being a pure raw material. This modification will usually affect the quality of the raw material in a negative way because the adulterant most often is of inferior quality.

Contamination (accidental or by carelessness) and poor processing (e.g., overheating of fishmeal and blood meal, or underprocessing of feather meal, etc.) also may have a significant negative effect on the quality of raw materials. Although not covered by the definition of adulteration, contamination and poor processing may be regarded as similar contraventions.

Examples of raw material adulteration

Brown fishmeal is clean, dried ground tissue of either undercomposed whole fish or fish cuttings, or both, with or without extraction of part of the oil (L. Bates, personal communication).

White fishmeal is dried, nonrendered, clean, undercomposed portions of fish from the fish-processing industry. It sometimes is also known as fish by-product meal.

Due to its high price, fishmeal is one of the favorite raw materials for adulteration. The various adulterants used differ usually, depending on the country of origin.

A number of fishmeal samples have been found to be adulterated in recent years. The preferred adulterant was feather meal, hydrolyzed to varying degrees. Fishmeal is sometimes adulterated with shrimp products (shrimp meal, shrimp head meal, and shrimp shell meal). A number of fishmeal samples recently were found to contain various amounts of lobster meal.

Poultry feathers have a crude protein (CP) content of approximately 84%. However, raw feathers are relatively insoluble, with a low digestibility (5%) due to the high keratin content and strong disulfide bonding. Fresh feathers are steam-hydrolyzed under high pressure and temperature (140°C) for a period of time sufficient to break the disulfide bonds. The digestible CP content of hydrolyzed feathers is approximately 57% (Chandler, 1993).

Incomplete (underprocessed) hydrolysis is often observed, and this understandably will have a negative effect on digestibility. In the majority of cases where fishmeal adulteration with feather meal was observed, the feather meal was poorly hydrolyzed.

The amino acid composition of fishmeal and hydrolyzed feather meal is presented in Table 1.

Fishmeal is rich in lysine and methionine, while feather meal is deficient in lysine and methionine. Hydrolyzed feather meal is rich in cystine, threonine, and arginine, but deficient in methionine, lysine, histidine, and tryptophan (Chandler, 1993).

Shrimp meal is the undercomposed, ground dried waste of shrimp and contains parts and/or whole shrimp. Shrimp head meal is the undercomposed ground dried waste of shrimp heads and should not contain additional exoskeleton, whereas

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### Table 1

The composition of fishmeal, hydrolyzed feather meal, blood meal, and carcass meal in terms of essential amino acids

<table>
<thead>
<tr>
<th>Amino acid (g/100 g)</th>
<th>Fishmeal&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Fishmeal&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Feather meal&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Blood meal&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Carcass meal&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>4.5</td>
<td>6.3</td>
<td>7.1</td>
<td>4.3</td>
<td>6.8</td>
</tr>
<tr>
<td>Cystine</td>
<td>0.9</td>
<td>1.2</td>
<td>3.2</td>
<td>2.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Histidine</td>
<td>1.6</td>
<td>2.5</td>
<td>1.0</td>
<td>5.4</td>
<td>1.9</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>3.5</td>
<td>3.6</td>
<td>4.1</td>
<td>1.1</td>
<td>3.2</td>
</tr>
<tr>
<td>Leucine</td>
<td>5.7</td>
<td>8.3</td>
<td>6.9</td>
<td>12.4</td>
<td>7.9</td>
</tr>
<tr>
<td>Lysine</td>
<td>6.2</td>
<td>8.5</td>
<td>2.3</td>
<td>8.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Methionine</td>
<td>2.3</td>
<td>2.6</td>
<td>0.6</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>3.1</td>
<td>4.5</td>
<td>3.1</td>
<td>7.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Threonine</td>
<td>3.2</td>
<td>4.7</td>
<td>4.0</td>
<td>5.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>0.9</td>
<td>—</td>
<td>0.5</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Valine</td>
<td>4.1</td>
<td>4.1</td>
<td>3.1</td>
<td>6.3</td>
<td>4.5</td>
</tr>
</tbody>
</table>

<sup>a</sup> Church, 1991.
<sup>b</sup> Erasmus et al., 1994.
<sup>c</sup> Chandler, 1993.
shrimp shell meal is the undercom-
posed ground dried waste of shrimp exoskeletons from cleanings.

Shrimp products, especially the exoskeleton, contain significant
amounts of nonprotein nitrogen (NPN) and, although it will raise the CP level
when added to fishmeal, it will lower protein and amino acid availability,
especially in monogastric animal diets. The NPN in shrimp products also does
not show up in a NPN analysis (L. Bates, personal communication), and
therefore implies high (normal) true
protein values in fishmeal.

Clam products, squid meal, and
sea meal also may occasionally be present as adulterants.

Meat and bone meal
Meat and bone meal may be defined as the ground, rendered carcasses of
large animals including bone. It
should not contain hide, horn, hoof,
blood, rumen contents, hair, or other
materials except what is unavoidable with good manufacturing practice.

The amino acid composition of
meat and bone (carcass) meal is pre-
sented in Table I.

A number of adulterated meat and
bone meal samples have been observed where the preferred adulter-
ant was feather meal, hydrolyzed to various degrees.

Horn, hoof, hair, hide, or blood
particles are always found in meat and
bone meal, but sometimes in such
quantities that would bring the meat
and bone meal to the very edge of
adulteration. Some samples may con-
tain hydrolyzed hair, which is quite
digestible as opposed to almost indi-
gestible raw hair.

Poultry litter (manure) also has
been found as adulterant in meat and
bone meal. The meat and bone meal
would then typically contain observ-
able quantities of feathers, sunflower
hulls, and wood shavings.

Blood meal is clean, heat-pro-
cessed blood from a rendering plant.
The blood meal may be spray-dried,
ring-dried, drum-dried, batch-dried, or
vac-dried. The amino acid content of
blood meal is presented in Table 1.

As in the case of meat and bone
meal, blood meal has been found to
contain poultry litter as contaminant.

Soybean meal
Soybeans may be used as such in ani-
mal feeds, or processed into one of the
following products: full-fat soybean
meal (roasted), ground extruded
whole soybeans, soybean oilcake
meal, soy flour, or soy protein concen-
trate. Full-fat soybean meal and soy-
bean oilcake meal are often used in
the mixed feed/food industries.

Some cases of soybean meal adul-
teration have occurred. In one case, I
found an imported soybean meal to
contain approximately 15% cotton-
seed oilcake meal. The CP content of
the two products may be quite similar,
and this type of adulteration may pass
very often without being detected.

Cottonseed contains gossypol, a yel-
low polyphenolic pigment that is toxic
to monogastric animals. Even cotton-
seed oilcake meal contains gossypol
and, depending on the cotton variety
and the oil extraction process, levels
may vary from as low as 200 parts per
million (ppm) to as high as 5,000 ppm.

Most modern oil mills use some varia-
tion of prepress-solvent extraction pro-
cedure, and cottonseed meal therefore
typically contains 200–900 ppm go-
syppol. Heat processing results in the for-
mination of various complexes, including
a gossypol-lysine complex. Although
free gossypol is the toxic form, some
complexes will result in a lower avail-
able lysine content.

Examples of contamination
Almost all feed raw materials are sub-
ject to contamination of some sort.
The source of contamination may either be from the environment (accidental)
or due to carelessness.

Examples of environmental con-
tamination include the following:
(a) Light particles, such as rice
bran, from a nearby plant may be car-
ried by the wind to contaminate feed-
stuffs. This type of contamination is
usually very mild and may be neglect-
ed for all practical purposes except, of
course, in the case of toxic or injuri-
ous contaminants.
(b) Hay may be contaminated with
weeds or unwanted species of other
crops (grasses/legumes).
(c) Grains/seeds often are contami-
nated with weed seeds. Contamination
may vary from negligible (most cases)
to quite serious. Injurious weed seeds
have been observed in some samples.
Examples of weed seeds that I have
observed in raw materials (e.g., in soy-
beans) include species of Ipomoea
(morning glory), Datura (jimsonweed),
Sesbania, Bidens, Vigna, Brachiaricia,
Polygonum, Cassia, Commelina, and
Cleome, as well as various grass seeds.

It is of interest to note that the country
of origin of the raw material may be
crucial. For example, according to toxic-
ologists, seed from the local (South
African) Ipomoea is not toxic, while
that from the United States is highly
toxic. According to Bromilow (1995),
the seeds of Datura spp. are extremely
toxic, while local (South African) toxic-
ologists were not able to induce toxic
symptoms in farm animals (even mono-
gastrics) when they were included in
their diets at fairly high levels (Fourie,
1994, personal communication).

Examples of contamination due to
carelessness or poor practices include:
(a) sand found in hay samples; (b) plas-
tic particles; and (c) glass powder,
found in one finely ground grain sam-
ple (it probably originated from a bottle
that entered the hammer mill together
with the grain); and (d) synthetic fibers
present in most samples. These fibers
usually come from container bags.

Although most contaminations are
harmless, care should always be taken
to minimize contamination and to pre-
vent injurious material from entering
feed and feedstuffs.

Poor processing
Fishmeal may sometimes be overpro-
cessed, although adulteration of fish-
meal seems to occur more often than
overprocessing. A small number of
carbonized particles are found in
almost every fishmeal sample. In
some cases, however, unacceptable
levels of carbonized particles may be
observed that would definitely affect
nutritive value and probably even total
dry-matter intake if mixed into a diet.

As mentioned earlier, raw feathers
are virtually indigestible, while the
digestibility of completely hydrolyzed
feathers may be quite high. Numerous
samples containing feather meal as
adulterant have been observed where
the feathers varied from raw to partly
hydrolyzed to completely hydrolyzed.
Hominy feed is one of the most variable energy foodstuffs in terms of fiber, fat, and energy content. This is due to the variation in germ content. Hominy feed always contains particles of the pericarp, hilar layer, and tip cap. Good-quality hominy feed will contain significant amounts of germ, while it will almost be absent in poor-quality chop.

Effect of adulteration/contamination/processing on quality

Modern livestock feeds and pet foods are formulated with the aid of sophisticated computer software to meet the needs of companion animals, working animals, and high-yielding farm animals in terms of a wide range of nutrients.

Feedstuffs such as fishmeal, blood meal, maize gluten-60, and even pure amino acids are used to “fine tune” the amino acid profile of specific diets. An example may indicate the effect of adulterated fishmeal on the amino acid profile of specific diets. An example may indicate the effect of adulterated fishmeal on the amino acid profile of specific diets. An example may indicate the effect of adulterated fishmeal on the amino acid profile of specific diets. An example may indicate the effect of adulterated fishmeal on the amino acid profile of specific diets. An example may indicate the effect of adulterated fishmeal on the amino acid profile of specific diets.

Fishmeal may be added at a level of 5% to supplement the methionine and lysine content of a diet. If the fishmeal contains 20% hydrolyzed feather meal (CP digestibility = 68%), the supplemented methionine and lysine will be reduced significantly. The effect will be even more significant if the feathers are raw.

Fishmeal adulterated with shrimp exoskeleton, blood meal with poultry manure, and meat and bone meal with feather meal will all have similar negative effects on diet quality.

Apart from the effect on nutrient availability, adulteration can have serious health consequences. In one observed sample, roasted full-fat soybean meal contained about 20% cottonseed oilcake meal. The gossypol content of cottonseed oilcake meal may vary significantly, but 850 ppm is a realistic value to use in an example. A pet food containing 15% of this soybean meal would have a gossypol content of about 26 ppm.

Many feed raw materials consist of various fractions due to anatomical structure. Fishmeal, for example, contains bone, scales, and muscle (meat), while meat-and-bone meal contains bone, meat, hair, and even horn and hoof particles. Grains contain kernel material and hulls, while forages contain leaf and stem fractions. All these fractions can vary due to processing methods, harvesting time, etc.

The bone-and-scale (BS) fraction (fishmeal) or the bone fraction (carcass meal) can be determined quite accurately by a trained feed microscopist.

Table 2 indicates BS values that can be accepted as normal variations in various types of fishmeal.

It is clear from Table 2 that fish waste added to “pure” fishmeal will increase the BS fraction. This will increase ash content and decrease CP content. Adulterants such as feather meal will decrease the BS fraction.

Values for bone fraction content of fishmeal, meat-and-bone meal, and poultry by-product meal probably would not be readily available in the literature. Values cited in this paper were obtained from the author's own experimentation. The bone fraction in meat-and-bone meal usually varies between 35 and 45%, although lower values have been observed in contaminated samples. The bone content of poultry by-product meal is much lower, and usually is less than 5%, but can be higher when the product contains heads and feet.

Although bone fraction values can vary in the mentioned samples, it gives one an indication of the type of material that is dealt with and often provides a clue for further investigation toward adulteration.

The BS fraction in fishmeal, the bone fraction in carcass meal and poultry by-product meal, the hull fraction in soybean meal, and various other fractions in food raw materials can all be determined quite accurately in a feed microscopy laboratory.

Quality control programs

The purity of feed/food raw materials used in diets is of utmost importance to ensure the quality of the end product. Everybody knows that the chemical analysis of any food source can vary quite substantially, and that there are logical reasons for much of this variation, e.g., age of plants at harvesting, cultivation, fertilization, ratio of bone to meat in carcass meal, etc. The variation usually is accepted as a normal occurrence, but the cause may often be attributed to the presence of impurities, poor processing techniques, contamination with undesired materials, addition of low-grade products (dilution), or partial substitution with inferior sources (adulteration).

Quality control programs should be comprehensive enough to explain reasons for variation in chemical composition. Chemical analyses to determine CP, fat, fiber, and mineral content are usually not complete enough. In some cases, analyses for amino acid and/or fatty acid contents will provide valuable additional information. These may, however, contribute to significant increases in cost and time. Feed microscopy is a powerful quality control tool and may provide valuable information on the purity and processing standards of food raw materials and in the identification of adulterants and contaminants.

Bibliography


