Particle Size and Mixing Problems for Aquatic Feeds

Sylvan Eisenberg and David Eisenberg
Micro Tracers, Inc.

The purpose of mixing any feed is to blend the specified nutrients so homogeneously that the animal can obtain all of those nutrients at each feeding. For a large animal consuming 20 kg at each feeding, the only requirement is that each 20 kg of feed be essentially the same as any other 20 kg. For a small animal, however, the level of scrutiny may be 10 g or less.

A 20 g shrimp will consume about 0.80 g of feed; smaller shrimp (2 g) consume about 0.25 g of feed, and shrimp in earlier stages of development will consume even less. The level of scrutiny is 0.80 g for 20 g shrimp and 0.25% for 2 g shrimp. The size of the feed unit becomes smaller,in proportion to the size of the animal, changing from large pellets to small pellets to crumbles to superfine feed.

Feed Size — Ingredient Size

Aquaculture feeds are often a mixture of many ingredients added at low inclusion levels. For example, an ingredient declaration describing a 250-400 micron larvae fish and shrimp feed can list 50 separate ingredients.

A formulated feed is a mixture of many components. Certainly, the size of any of the individual components must be significantly smaller than the unit size of the feed pellet, crumble, or granule itself. Just how much smaller it is will depend on its proportions and the size of the feed unit. This can be estimated in the manner described below.

To simplify calculations, we will assume that all feed units are spherical and of unit density. Although these assumptions introduce sizeable errors, they are insignificant for the present purpose. Furthermore, we will specify an addition of 1% of a feed additive to be within +/- 10% of specification to each feed unit. To meet this requirement, Poisson Statistics will be applied. The standard deviation of the random distribution of particulates equals the square root of the number of particles involved. Therefore, each feed unit, pellet, crumble, or granule D_1 mm in diameter must contain 100 particles of feed additive which are D_2 mm in diameter. Given D_1 and the percentage (P%) of additive in the feed, proceed as follows to estimate D_2, the diameter size of the additive particulates. Note that weights are considered equal to volumes, and that volumes are porportional to lengths cubed. Therefore:

1) $100 \times D_2^3 = (P/100)\ D_1^3$
2) $D_2 = 0.046416 \times D_1 \times P^{1/3}$

Now, consider a 20 g shrimp consuming about 0.80 g of feed per day. The feed form would probably be crumbles, each feed unit about 2 mm (D_1) in size, and weighing approximately 4 mg with about 200 such units consumed per day. Consider next the physical specifications of a 1% additive (P).Assume this feed additive should be present in each feed unit at +/- 10% level of its specified value; that is, it should be 0.04+/-0.004 mg per feed unit. Limiting the variation at this level requires that in the .04+/-.004 mg there should be 100 particles (D_2) of the additive in each unit of the feed; each particle of additive must weigh 0.0004 mg (0.4 mcg) corresponding to particles about 93 microns (170 mesh) in size. The addition of feed additives presents a problem not only in particle size reduction for uniform mixing of an aquatic feed but also in achieving that degree of particle size reduction without damage to the ingredients prior to mixing. Other problems can occur when working with fine ingredients that may not be apparent in animal feeds containing coarser ingredients.

Fine Powders

Commercial aquatic feeds can range in particle size from 50 to 2500 microns; from superfine powders to crumbles to pellets. These feeds correspond to roughly 270 mesh to 8 mesh, respectively. Ingredients used to produce such feeds must undergo particle size reduction in order to obtain a uniform mix at that feed unit size. Many of these will be extremely fine powders which may display unexpected properties.

Powders clinging to sidewalls of mixers, ducts, and bins usually a result of electrostatic charges. These develop on the electrically non-conductive powders as a consequence of the mechanical action of mixing. Electrically grounding the equipment will help relieve this problem.

Electrostatic forces are long range forces; they diminish relatively slowly with increasing distance between charged surfaces. The force is inversely proportional to the square of the distance between them. The effectiveness of these forces can be easily demonstrated by putting a few milligrams of large 40-80 mesh graphite particles into a polyethylene bottle and shaking them. Although they are relatively large particles, the long range forces are adequate to hold them tightly to the side of the bottle.

Very fine powders adhere to surfaces by another mechanism not applicable to larger particulates. They adhere to surfaces or cohere to themselves because of short-range molecular (van der Waals) forces. These decrease as the seventh power of the distance between surfaces and are manifested only by very small particles that can get very close to a surface. This is exemplified by the clumping of fine powders and their adhesion to surfaces. It is also exemplified by the near-welding together of optically flat surfaces when contacting each other.

The requirement for small particle size in the ingredients used for aquatic feed formulations, therefore, imposes problems beyond those encountered in the production of feeds for large animals such as cattle and swine.

Quality Control

The requirement that every feed unit, whether it is 50 or 2500 microns in size, must correspond reasonably in composition to the gross specification is not easily achieved. Consideration must be given to the particle size of each ingredient as related to its proportion in the formulation. Assuming that such requirements have been met and all ingredients have been added to a mixer and mixed, discharged, conveyed, pelletized, crumbled, screened, and packed, then what must be done to ensure the soundness of the product, at least in terms of mixing? Simply look for a unique minor component (which originates from only one ingredient or additive) in the individual feed units (pellet, crumble, or superfine) or in that number of feed units corresponding to a single feeding. Each feeding should contain that unique ingredient at its statistically defined level.