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Least-cost formulation software in shrimp aquafeed production

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Maximizing nutritional content, lowering costs, increasing profits

The use of feed formulation software has helped aquafeed formulators design feeds that maximize nutritional content for their species while lowering costs in order to increase profits.

The success of aquafarmers depends on several parameters. One of the most important ones is the quality of aquafeeds used for broodstock maturation, larval rearing and farm grow-out to market size. In the latter, cost of aquafeeds can account for more than 50 percent of the production cost, so it is critical that quality feeds are used. The quality of shrimp grow-out feeds depends on several factors, including the use of good ingredients, and proper formulation, manufacturing and management. Here I will discuss the use of least-cost feed formulation software.

Nutritional requirements and formulated aquafeeds

The nutritional requirements of penaeid shrimp, their feed formulation and manufacture have been extensively discussed and documented, but there is still much to learn. The essential dietary nutrients for shrimp include amino acids, fatty acids, energy, phospholipids, cholesterol, minerals and vitamins. With industry expansion there has been an intensification of production and an increased dependence on the use of manufactured dry feed, which often represents the highest production cost.

Protein is typically the most expensive macronutrient in shrimp feeds, and dietary protein levels from 18 to 60 percent have been recommended for various species and sizes of marine shrimp species, possibly due to their wide range of natural feeding habits. Postlarval shrimp require a higher dietary protein level than older shrimp. As production intensity increases, so does the importance of a balanced feed. Most extensive shrimp farms work at very low stocking densities and do not apply formulated feed, while semi-intensive farms depend on feeds for at least the last two-thirds to one-half of the production cycle, and intensive farms shrimp depend on commercial diets for most of the production cycle.

Formulated shrimp feeds are complex products and the main components have traditionally been, depending on the species, fishmeal (0 to 30 percent), wheat flour (20 to 35 percent) and soybean meal (15 to 35 percent), These few ingredients contribute most, if not all, of the protein, amino acids and energy, while the remaining is comprised of several other ingredients (including various lipids) and microingredients that contribute the balance of essential fatty acids, vitamins, minerals, attractants, binders, preservatives, pigments and health additives.

Around 110 additives are believed to be the most common ingredients used in shrimp feeds today. Attractants include animal byproducts (crustacean meals, squid byproducts, low molecular weight fish and meat extracts) and purified compounds (free amino acids, artificial flavors, betaine and nucleotides). Enzymes supplements improve digestibility of phytate, fiber, indigestible sugars, and other components. Various additives, including coccidiostats, antibiotics and hormones have been used as growth promoters in shrimp.

Other additives, including immunostimulants, probiotics and vaccines, are being used to stimulate the shrimp's immune system of shrimp and improve disease resistance to disease. This has become especially important to reduce outbreaks of shrimp viral diseases. Immunostimulants used include beta glucans, bacterial extracts, blood plasma, seaweed byproducts and yeast. Probiotics – live cultures of beneficial bacteria added to some culture systems and feeds, typically larval diets – are another type of additive. Grains used in shrimp feed can be infected with fungus, which can expose shrimp to mycotoxins. Several products are used to absorb mycotoxins and reduce their toxicity.

The main lipid additives are essential fatty acids, phospholipids, emulsifiers and cholesterol from fish and squid oil. The primary source of supplemental phospholipids for shrimp diets is lecithin. Cholesterol is another essential nutrient for shrimp, and even though it is naturally present in fish oil, fishmeal, shrimp head meal and squid byproducts, it often has to be added to reach needed levels.

Shrimp diets are often supplemented with phosphorus and a complete trace mineral and vitamin premix. Vitamin C is rapidly lost during storage and exposure to heat and moisture, and a stable form is typically used, such the polyphosphate, monophosphate-Ca, monophosphate-Mg, or encapsulated ascorbic acid.

Understanding aquafeed formulation

Formulation involves the determination of the amount of each ingredient to include in a particular formula, to provide all required nutrient levels for the target species and stage of development. Formulation is a dynamic process, as changes in ingredients or prices will necessitate a change in the formula to ensure that the profile of nutrients in the designed formula is maintained. A common misunderstanding is that once a formula is developed, it will not need to be modified. Not true, unless the ingredients' nutrient profiles do not change, and this is seldom the case, because ingredients can vary within an adequate range and every time there is a deviation outside the acceptable range a new formula must be produced.

In the recent past, animal feed manufacturers used to balance their feeds using hand calculations, and very often relied upon using tedious trial and error methods. For over three decades, many industries have increasingly relied on computer software to solve many problems and the aquaculture industry is no exception to that. In the late 1960s commercial computer software for solving least-cost formulation began to emerge in the market place. These early systems were used on dial-up terminals of mainframes. Although infinitely faster than solutions by hand, they were slow, cumbersome and extremely expensive compared to systems available today.

The development of computer technology and the increased use of linear programming provided the incentive for the first practical least-cost formulation software implementation in the late 1970s, but the breakthroughs only arrived in the 1980s with the advent of personal computers. The development of high-quality formulation programs necessitated a very specialized and unique combination of experience, education, talent, commitment and dedication in various areas, including knowledge of the nutritional requirements of animals; nutritional content of ingredients; availability and cost of feed ingredients; mathematical programming; and computer programming.

Least-cost formulation software to optimize profits

The technique of least-cost feed formulation consists of combining many feed ingredients in a certain proportion as to provide the animal with a balanced nutritional feed at the least possible cost. As such, it requires the professional knowledge of the animal practitioners who can consider special contemplations for the aquaculture industry such as the pellet size, shape and consistency. Other factors specific to the aquaculture industry, such as feed floatability, fast or slow sinking feeds, and life span specific nutrient feeds, must be considered. People involved in formulation must be aware of the variations of nutritional requirements for different species, because aquatic feed formulation needs can be diverse.

Several feed formulation software packages are available on the market. Animal feed formulation is not a new activity, but new and innovative software tools are being developed and introduced into the market every year. These tools enable animal practitioners to maximize nutritional content that may vary at different verse ages and stages in production while controlling costs in order to maximize profitability.

Least-cost feed formulation is an important component within formulation and profit maximization. There are several companies producing computer software for feed formulation. These software packages vary from simple solutions to sophisticated and complex software packages designed for large feed manufacturers that require multi-site, multi-server and multi-blending capabilities. Along with providing feed formulation solutions, these multifaceted software packages can also provide modules for inventory control and production as well as interfaces to accounting systems. And some feed formulation software is specifically designed for a certain species and it may provide tables of nutrient requirements for those specific animals.

Managing formulation effectiveness

For least-cost feed formulation software to be efficiently used, it should offer several basic features applicable to the targeted species. The results of feed formulation are based on the data entered by the user and the final formula will only be as accurate or cost-efficient as the data input.

Feed formulation software provides a way of entering data on the ingredients available for formulation into the software program. Available feed ingredients must be listed along with their cost per unit price. Depending on the software being used, optional ingredient properties also can be entered, including ingredient types, alternate code names, applicable species and others.

Specifications must be given for each formula to be solved by the least-cost formulation software. Formula specifications are defined by the nutrient requirements or constraints and by the ingredient limits. In each case, the formulator specifies either a lower limit and/or an upper limit for each item in the formula.

The values for nutrient compositions are preferably known from *a priori* chemical analysis results of a representative sample of the ingredient. When not available, relevant published tables of feed composition using average or typical values may be used instead.

Once all the necessary information is provided, the feed formulation software will produce formulas that will meet the desired specifications at the lowest possible cost. A requirement for proper formulation, however, is that the formula result must be feasible both from a mathematical and a nutritional standpoint. If impractical results are obtained, the ingredient and nutritional composition should be carefully checked and reviewed to make sure the solution is nutritionally acceptable for the targeted species.

Selection of ingredients

One of the most important uses of least-cost feed formulation is in the decision making to select among the ingredients available ingredients to be used, based on their nutritional composition and cost. Often one ingredient can be substituted for another with the similar nutritional value, and this can be helpful if market conditions favor the use of one ingredient over others to achieve the highest profit margin while still maintaining sound nutritional viability. In addition, the following concepts are important in the analysis of the formulation results.

Shadow prices

By subtracting the marginal cost change from the current ingredient cost the resulting cost is called the shadow price of the ingredient. This amount represents the cost of the ingredient at which the ingredient can be included in the formula. Ingredients that are included in the formula results have a shadow price of zero. Similarly, the change in formula cost with a change in a nutrient restriction is called the shadow price of the nutrient. In a least-cost feed formulation, the shadow price of a nutrient is zero if the level of nutrient use is not equal to the constraint level.

Marginal price changes

For those ingredients that were not included in the formula solution; the least-cost formulation software can indicate how much the cost of these ingredients will have to fall before they can be included in the formula. This cost change is called the marginal price change of the ingredient.

Parametric price changes

An important analytical use of least-cost feed formulation software is to observe the impact of changing ingredient prices in the formula solution. This allows the user to determine how much of an ingredient would be used if the ingredient were available at a different price. To carry out this analysis, the ingredient price can be adjusted and recalculations done as many times as necessary. Some feed formulation software allows the generation of summary graphs called price maps, which are the result of plotting the formula costs at different ingredient prices.

Nutrient factoring

The ability to specify that several nutrients must be present in the resulting formula in relation to one another is referred to as “nutrient factoring.” Advanced least-cost feed formulation software provides this capability which allows setting a ratio between two nutrients. The ability to change nutrients in proportion to one another is useful to the user because of the way samples of the same ingredient differ. For example, the user can specify that nutrients such as Arginine, Histidine and Isoleucine be proportional to the total amount of protein in the formula.

Optimum density

This refers to a technique of least-cost feed formulation that tries to formulate with specific proportions among nutrients by relaxing the weight constraint of the formula, based on the theory that animals will consume feed to maintain a constant energy intake regardless of the energy level of the feed.

Multi-blending

Feed formulators sometimes have to decide based on having limited amounts of some ingredients. An advanced feature of some least-cost feed formulation packages is multi-blending, which allows more than one formula to be solved at once while considering the ingredients that are available in limited qualities. The program calculates which formulas must use the scarce ingredients in order to achieve total least-cost solution.

Perspectives

For many years, manufacturers of commercial aquafeeds balanced feed formulations for their animals by using tedious trial and error methods which compromised nutritional quality and lead to lost profit potential. The use of feed formulation software has helped aquafeed formulators design feeds that maximize nutritional content for their species while lowering costs in order to increase profits.

The aquaculture industry shares many of the same issues as other animal practitioners but it has some very unique challenges regarding feed formulation that must be taken into consideration. It is vital to remember that, as with any software, the end product is only as good as the data with which it was formulated.

The use of software technology has greatly improved both animal nutritional health and practitioner profitability. Additional advances in nutritional knowledge and manufacturing technology, as well as novel ingredients, will make this technology increasingly important.

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