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Presentation by

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Optimization in the round – the bigger picture

Taking account of non-nutritional parameters such as plant and energy constraints within the formulation process

Overview:

Whilst achieving the least cost recipes within nutritional specifications is the main purpose of feed formulation software, the decisions made by formulators in these recipes can have unforeseen consequences when it comes to their production; consequences which can have a significant impact on the rest of the process and the true cost of the finished product. These aspects can be hidden from, or even ignored by formulators, but, if taken into account, may alter ingredient purchasing decisions, recipe and production costs and, ultimately, profitability. This presentation looks at some techniques which can be used in formulation software to incorporate these wider considerations, giving the formulation role a broader perspective and resulting in a better model of the feed manufacturing process.

Within the feed industry, the use of formulation software is a long-established technique for deriving least cost recipes, of various types, to pre-defined nutritional requirements. The technique is employed to achieve these recipes in the context of fluctuating cost, availability and nutrient analysis of raw materials used. The technique is also logically extended to assess raw material value, since each raw material can be said to be in "competition" to provide the required nutrients. Formulation software uses mathematical techniques which enable the value of any raw material to be expressed in economic terms. This value depends on the nutrition it contributes in comparison to its cost, within the context being examined.

Traditionally, the formulation function primarily focuses on nutritional needs. However, we all know that when finalising recipes for the production of animal feed there are other considerations to be taken into account. For example, certain raw materials cannot be used at high levels due to anti-nutritive factors or poor palatability effects, or there are some raw materials which must be controlled in order to ensure a good finished product quality.

Hence there are numerous factors, many of which are not directly nutritional, which must be considered in the formulation process. In this presentation, I am going to discuss a few techniques which can be employed to bring a more rigorous approach to the challenge and also exploit the power of the formulation software to achieve better results, more efficiently.

Why consider non-nutritional parameters

First of all, why is this necessary? Why consider non-nutritional parameters in the formulation process whose aim is to achieve a nutritional requirement? The simple answer is "financial". There are many other reasons too, such as appropriate raw material selection and purchasing policy, customer satisfaction from product quality and performance and efficient production with low wastage. However, all of these reasons will eventually feed back to a financial result.

Techniques and examples

Techniques to incorporate these issues are based on the following –

- Nutrients, or "characteristics", used to represent a non-nutritional factor.
- "Virtual" raw materials. These are not real raw materials but can be used to "collect" features from across multiple materials into a single parameter for constraint.
- Relationship constraints.

Owing to the nature of these techniques, not all formulation software packages can support them. In addition, some questions can be product-specific, whereas others relate to the production facility, or even the company, as a whole. The appropriate technique must be chosen.

In some ways, the main technique is the user's creativity or imagination, to find a way to analyse the problem and articulate it in a way that can be used by the formulation software.

Example 1 – Physical quality parameters

Customers are looking for a product with good physical quality. "Quality" can be subjective, but typically means a durable pellet; fishfeed that floats; a petfood with the right colour: aspects that result in low wastage. Various measurements can be applied to the finished product to ensure that it meets such requirements.

As for the formulation function, most feed mill managers and nutritionists will be aware of the effect of certain raw materials on the finished feeds quality. If we could capture that knowledge and put it into the formulation process, then the recipes produced and passed on to production would be more suitable and there should be less need to make changes and adjustments as a reaction to quality problems. This would, in turn, reduce wastage.

Approach 1 – Constrain problem raw materials. If a raw material is known to have a negative effect on quality, then limiting how much of it can be used in a product is the standard method of preventing quality problems from this cause. A maximum constraint on that raw material in the product specification, lower than could be permitted on a pure nutritional basis, is the usual way this is managed.

The problem with this approach is that it is too simplistic. It fails to easily accommodate the fact that the inclusion of another raw material with a very positive effect on quality may mean that more of the problem material could have been used, thus reducing the cost of the product. This scenario would have to be tested manually.

Approach 2 – Create an index of quality and constrain this quality parameter. A new characteristic can be created to express the quality parameter. Each raw material is given a value for this and the specification is given an appropriate target which must be met when optimised.

This approach allows the optimisation to “choose” an appropriate mix of raw materials, saving money whilst also making a more accurate prediction of quality. The difficulty is making a measurement of the parameter for each raw material. This often comes from experience, and may be refined over time.

The following table illustrates these contrasting approaches. Diet A restricts the amount used of certain “problem” raw materials to maintain quality, whereas diet B is formulated to a target index (the same as achieved in diet A), thus allowing more flexibility in the use of the problem materials and potential cost saving –

Raw material	Cost	Quality Index		DIET A	DIET B
WHEAT	82	8		63.18046	62.30307
MAIZE GERM	110	4	Restricted	2.5	2.791957
MIDDS	83	6	Restricted	3	5
HIPRO SOYA	154	6		24.78541	24.1806
MOLASSES	50	5		0.753097	0
DCP	179	2		0.947793	0.882421
LIMESTONE	19.7	2		1.317751	1.239302
SALT	68.7	2		0.329325	0.332576
LYSINE	1950	2		0.585224	0.588965
FAT	178	4		1.689668	1.937636
SOYA OIL	300	2		0.711272	0.543475
SUPPLEMENT	3500	2		0.2	0.2

QUALITY INDEX = 7

Cost diet A =	121.33
Cost diet B =	121.16
Saving =	0.17

Further comments

Of course, the most accurate prediction of quality may not be just a simple sum, as shown above. Interactions between raw materials may have an effect.

In this case, the use of “Relationship” constraints in a specification may be useful. These allow two factors in a specification to be related together when optimisation takes place. These factors may be nutrients, raw materials, or groups of raw materials or nutrients. Any two of these may be added together, subtracted one from the other, expressed as a ratio, or one as a percentage of the other, with a minimum or maximum constraint applied. This constraint must be obeyed by the optimisation in order to bring about a feasible result. For example, it would be possible to constrain the total amount of raw material C and raw material D using a relationship constraint.

Note that the quality target is affected by the plant itself. Different plants may need to have different targets to achieve the same finished product physical quality. Changes in equipment may mean that such targets can be modified. The formulation software can therefore be used to assess the cost savings which can result from changing a physical quality target on a recipe, and thus provide justification for capital expenditure at the plant.

<u>Example 2 – Plant design constraints</u>
Whilst each of the examples we are discussing are, in some senses, a consequence of some aspect of plant design, a more obvious design constraint is something like a limitation on the number of silos. A very simple technique can be used to quickly evaluate a) which is the most optimal raw material selection to use in the available silos or, b) what the saving would be if additional silos were available.

This question is best examined using a multi-product optimisation. This gives a full overview of the problem and, more importantly, the object of such optimisations is total least cost.

In the optimisation solution, by switching on and off different combinations of the raw materials available, the user is able to compare alternative solutions for cost and content. For example, if there are 4 silos available for 6 materials, try different combinations of 4 from those 6 to find the global least cost solution. This is a creative approach, using the software to represent, or model, a real-life situation. You could say it views the plant as one big recipe, attempting to “optimise” the available resources. Without considering this type of question, many problems will be caused for production in terms of storage and handling.

Format International has a module, Bin-Mix™, which evaluates such questions automatically, ranking each alternative solution in order of cost.

<u>Example 3 – Moisture change</u>
Perhaps the most commonly applied outside factor in optimisation of animal feeds is moisture change. Target finished product moistures are often known, as is the moisture of the raw materials being processed.

The real effect on the product of moisture addition and loss can be incorporated and this is beneficial in terms of nutrition and cost prediction. Consider a process that loses 2% moisture. 100 tonnes of raw material weighed at the start of the process results in 98 tonnes of finished product at the end of the process.

This has several side-effects – The real cost of each tonne of feed is actually higher than predicted, as are nutrient levels. For example, a formula optimised to a minimum of, say, 21% protein, is concentrated to 21.43% in the finished product. Its cost may have been optimised at 121.16, but in reality it will cost 123.63 per tonne.

If moisture loss was included in the optimisation process, the correct starting weights in order to result in 100 tonnes of finished product (102.04 tonnes when there is 2% loss) would be predicted and nutritional targets could be met more accurately in respect of the finished feed. This gives a proper prediction of finished product cost, which is also lower than if loss is not taken into account.

For this to work, your formulation software has to be able to support particular features, for example negative inclusion levels.

Example 4 – Production rates, throughput and energy use

Other factors such as throughput, production rates and energy use also affect the true cost of the finished feed. These factors may also be incorporated in the optimisation of feeds. This will result in improved cost prediction and obtain better recipes for production, which are less subject to change or problems.

For example, it may be desirable to control production throughput. This can come from a simple desire to avoid blockages in a press and thereby reduce downtime. It recognises that the nature of the mixture can have a significant impact on production efficiency. In this sense, throughput of a mixture in production can be tackled in a similar way to the quality issue, with a suitable characteristic measuring the effect of each raw material on throughput, and the specification, when optimised, must meet an appropriate target value for this nutrient.

Production efficiency can also be examined in a wider way within the formulation function. Imagine you had a limited amount of production hours, or you wanted to produce recipes which minimised the cost of the energy taken to manufacture them. Flexible formulation software allows you to test these questions. It is possible that the resulting recipes cost more in pure raw material cost terms, but, overall, due to their effect on energy consumption in the plant, total cost is reduced.

These are real, live issues. Industry studies in 2008-2009 in the UK estimated that it may be possible to reduce by 15% the energy consumption of pelleting, through more careful selection of ingredients in the formulation. Since pelleting (including conditioning) accounts for about 70% of overall energy costs in a typical mill the study estimated that the UK feed industry may, through energy efficient formulation, be able to reduce its carbon emissions by 10kt/year (expressed as CO_2). The same UK study found a high correlation between the press throughput and the electricity use, with higher throughput recipes resulting in lower energy consumption.

Format International is leading a project, with industry partners, in collaboration with the UK government body, The Carbon Trust, to research the effect of individual raw materials on energy use and energy optimisation techniques.

So for the next example, let’s imagine we had a good idea of the production rate of a tonne of each of our products. With the use of the “virtual raw material” technique we can quickly visualise, in a multiple product optimisation, or Multi-Mix®, the total production time.

- First we create a nutrient or characteristic to represent the production rate in hours per tonne.
- In each specification we add a constraint against this nutrient to match the known production rate. So if the production rate was 10 tonnes per hour, we should constrain this nutrient to minimum and maximum 0.1 (i.e. it takes 0.1 hours to manufacture each tonne).
- Now add a raw material to represent the Production. This is a special sort of raw material, known as a “dummy”, that will have no effect on the nutritional analysis of the product. The way to do this is to leave all values of nutrients at zero, except for the production rate nutrient, for which it should have a value of 1.
- Finally, add this raw material to all specifications.

When optimising all products as one global problem, a “Multi-Mix®”, each product will use the production raw material at an appropriate level. In the Multi-Mix results, the usage will be multiplied by the tonnage of each product, giving a total production time. By adding a suitable cost to this virtual resource, the production cost can be derived.

This approach can be used as a basis for more complex work. For example –

- Production time can be linked to energy consumption, with appropriate costs allocated.
- This could be further refined using measures of the effect of individual raw materials on energy consumption. This would enable the optimisation to be constrained to reduce energy consumption by the plant, and feedback to the selection of ingredients.
- The virtual raw material technique has been applied to many other situations –
    - The production of powders from wet materials, adjusting raw material selection based on available drying capacity.
    - Incorporation of other costs, such as labour or packaging.
    - Controlling proportions of associated raw materials.

Conclusion

This discussion has illustrated some creative techniques which can be employed to extend the use of formulation software to consider non-nutritional parameters that have an impact on the feed manufacturing process. It is important to consider these factors since they have an impact on raw material selection, recipe design, recipe cost and the production process.

It is common to find formulators passing recipes to production which do, in fact, cause problems. The problem could be using an inappropriate number of raw materials, or recipe designs that cause quality issues. Whatever the situation, it is usually down to a lack of communication between the interested parties. Understanding the issues and applying appropriate techniques can improve results, raw material selection and cost prediction.

However, a note of caution must be sounded. Be clear where constraints come from – do not lose sight that non-nutritional parameters can often be a consequence of the current context. They should be re-evaluated and challenged regularly, and re-evaluation may mean assessing whether investment is appropriate in order to remove the constraints. In this case, formulation software assists with the cost-benefit analysis.

By contrast, these types of constraints may, in the right hands, be used to reduce the overall cost and enable feed manufacturers to act responsibly in their approach to energy and resource consumption, even if recipe raw material cost may increase.