# Evaluating the Cost Effectiveness of Feed Additives

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## Take Home Messages

- Economic evaluation must be done on a marginal basis.
- Management must understand all the dimensions of production affected.
- Improved feed efficiency (digestion) and/or the dilution of animal nutrient maintenance requirements.
- Management must understand all the direct and indirect costs.
- Management must understand the risk attributes (type I and II error, real options).

## Overview

Feed additives are a critical input technology for the successful management of the modern dairy operation. Feed additive products are continually evolving, and can impact the dairy operation in a number of dimensions. Feed additives are part of the wealth creation activities of a successful dairy. While feed additives may differ in their impacts, they share common economic attributes, which will be the main focus of this manuscript. Dairy managers should continually evaluate available products in terms of their potential impact on the economic efficiency of their operations.

## Background

Feed additive products are often initially explored through well designed research trials to determine their production attributes. Successful additives are embraced by the industry at large, and often become part of the new “norm” of dairy management. Listings of products and their production impacts can be found at the DeLaval web site:

www.milkproduction.com/Library/Scientific-articles/Nutrition/Feed-additives, and in the proceedings paper presented by Dr. Hutchens at the 2014 Penn State Nutrition conference (Hutjens, 2014). This paper will focus on the major underlying economic principles that are relevant to most feed additive products.

A critical issue in determining if a feed additive is to be used is what are the relative costs and benefits associated with the product. The most common and major impact of a feed additive is the effect it has on milk yield, composition of milk, and feed efficiency. Impacts in these dimensions directly affect the revenue stream value associated with the product, and must be accounted for in the economic assessment. There are other possible benefits beyond milk yield, which include reduced disease prevalence and/or severity, improved feed efficiency, improved reproduction efficiency, and potentially improved longevity. The potential economic value of these dimensions often require the use of specifically designed economic models that can account for the correlation of impacts or the use of general summary estimates (disease costs/case, cost/day open etc.). These broader potential impacts of feed additives will not be explored in this paper.

The cost associated with the use of a product is more complicated and can have a number of important nuances. First, the direct cost of the product must be adjusted in terms of the number of animals that are offered the product versus those animals in which the benefits are likely to be accrued. For example, a feed additive to reduce the incidence of milk fever will accrue costs for all animals fed within a pen (1st and > 1 lactation animals), while the benefit, a reduction in milk fever prevalence, will be realized primarily by the older lactation groups. Management can alter the cost associated by using these types of products targeting specific high risk groups (separate feeding pens); however, there may be additional costs associated with those actions.

One of the most important costs associated with the use of a feed additive product is the consequential impact it may have on dry matter intake. Feed intakes may be increased resulting in an increase in milk yield; however, the feed consumed may be digested at an altered efficiency (increase, decrease, or no change) and thus have different associated costs. Feed additives can vary in terms of their mean responses as well as their variation of responses. Additives that have greater variation in response will carry greater risk (expected value of failure) than products with lower response variation.

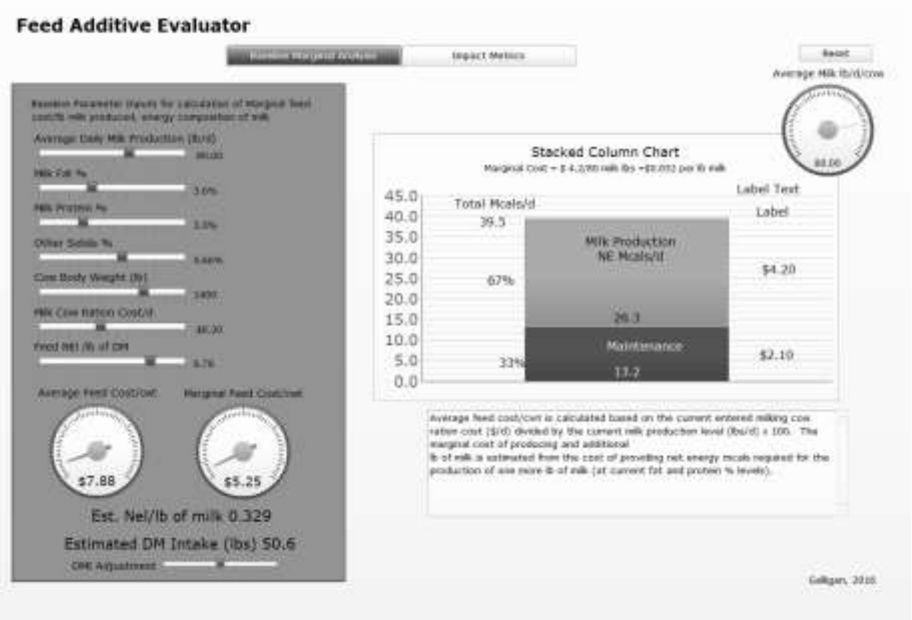
This paper will focus on the impact on milk yield, milk composition and feed efficiency. The general economic issues will be covered and presented in visual analytical tools (dashboards) that can be used to evaluate the economic impact and facilitate management decision making.

## ■ Milk Response Evaluation

The milk response should be evaluated in terms of incremental increase in yield and changes in composition (fat and protein %). The economic value of the associated increase in yield should reflect any compositional changes. A convenient approach is to look at the energy composition of milk as a function of the component values (milk fat, protein and other solids) and thus the total energy required to produce a given yield. The ration cost can be partitioned by the portion of feed energy used for animal maintenance (a function of body weight) and the portion used to produce a given yield and composition of milk.

A visual analytic (dashboard) has been created called the Feed Analytic Evaluator, which can be used to facilitate the economic evaluation of feed additives. This interactive tool can be found at Dapdairy.org (Logon: guest, Password: guest) under the Dashboard menu and in the Economics subsection.

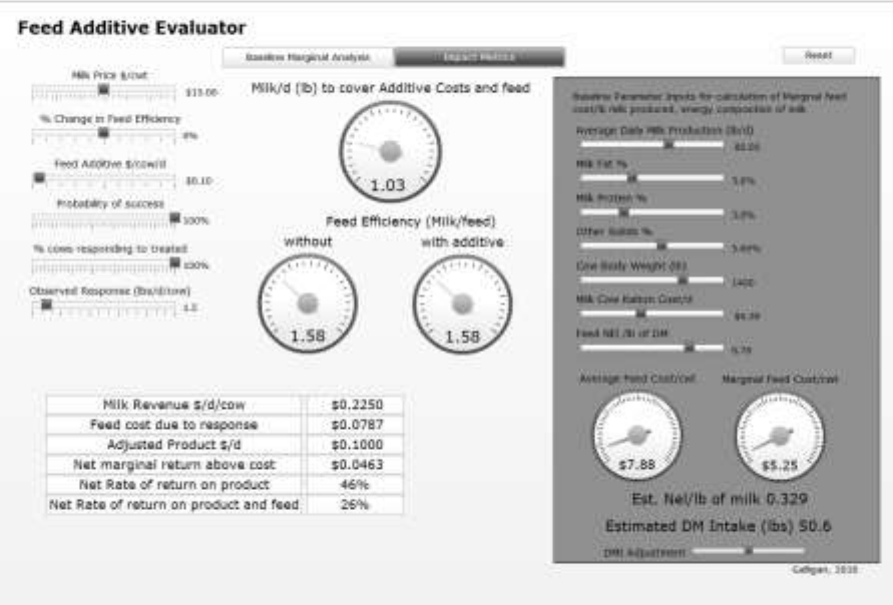
Figure 1 is a screen shot of the baseline screen. Here, baseline parameters are entered to describe the herd in terms of animal weight, milk level, milk composition, ration energy density and ration cost. From these parameters, the average and marginal feed cost of producing an additional lb. of milk can be estimated and expressed on a per cwt milk basis (Note: all prices are in US$). The average feed cost was estimated by taking the ration cost ($6.30) divided by milk yield (80 lbs/day) multiplied by 100 giving $7.88/cwt of milk. The marginal feed cost can be determined by estimating the portion of feed energy used to support maintenance versus yield. Based on the entered values, 39.5 Mcals of net energy are required for maintenance and production; approximately 67% of the total energy is used for production while 33% is used for maintenance (Figure 1). The ration cost can be partitioned (based on energy use) into $4.20 for production and $2.10 for maintenance. The $4.20 can be divided by the milk level (80 lbs) to yield a marginal cost of $.0525/lb of milk or $5.25/cwt milk. If there is no change in feed efficiency, the next marginal lb of milk is estimated to cost $.0525 to produce. The energy required per lb of milk at the entered composition is 0.329 Mcals/lb of milk and the cow is estimated to have an intake level of 50.6 lbs of dry matter.



Average feed cost/cwt is calculated based on the current entered milking cow ration cost ($/d) divided by the current milk production level (lbs/d) x 100. The marginal cost of producing and additional
lb of milk is estimated from the cost of providing net energy mcals required for the production of one more lb of milk (at current fat and protein % levels).

**Figure 1: Base parameter screen of the Feed Additive Evaluator dashboard.**

The next steps in determining the economic value of a feed additive are to describe its observed impact and various parameters. Figure 2 is an example of a product costing $0.10/cow/day and expected to increase milk yield by 1.5 lbs/cow/day with the baseline composition parameters. Feed efficiency is not changed, the probability of success is expected at 100% and the % of treated cows responding to treatment is set at 100%. Based on these parameters, 1.03 lbs of milk are required to cover the cost of the product and associated change in feed intake to at least break even. The actual partial budget is presented on the lower left of Figure 2, where a milk revenue is estimated at $0.225 and an associated marginal feed cost of $0.0787. After accounting for the daily cost of the product, the net marginal returns above costs is $0.0463/cow per day, yielding a 46% net rate of return per dollar of the additive cost and a 26% net return on the products and feed costs.



Milk Price $/cwt
% Change in Feed Efficiency 0%
Feed Additive $/cow/d $0.10
Probability of success 100%
% cows responding to treated 100%
Observed Response (lbs/d/cow)

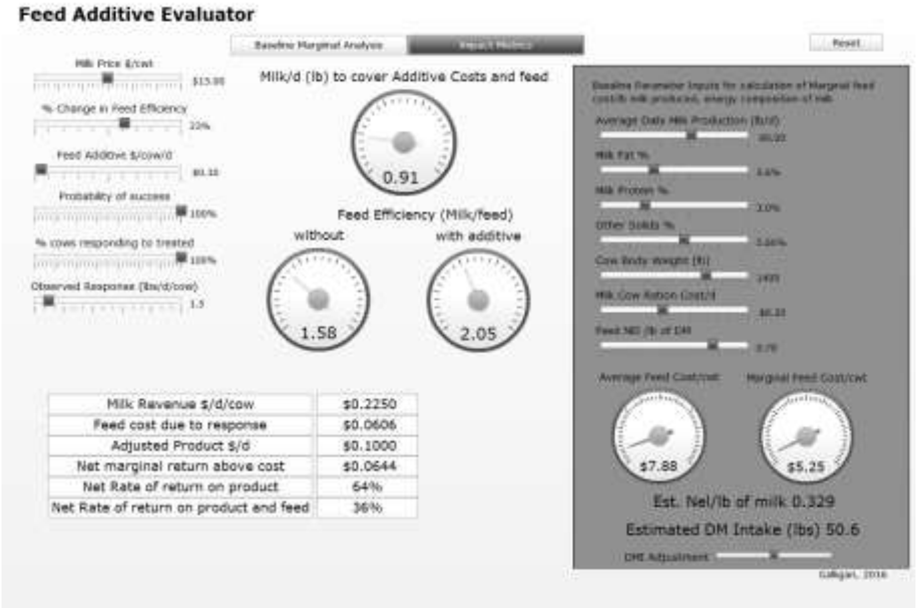
Average Daily Milk Production (lb/d)
Milk Fat %
Milk Protein %
Other Solids %
Cow Body Weight (lb) 1400
Milk Cow Ration Cost/d
Feed NEl /lb of DM

Est. Nel/lb of milk 0.329
Estimated DM Intake (lbs) 50.6

| | |
|---|---|
| Milk Revenue $/d/cow | $0.2250 |
| Feed cost due to response | $0.0787 |
| Adjusted Product $/d | $0.1000 |
| Net marginal return above cost | $0.0463 |
| Net Rate of return on product | 46% |
| Net Rate of return on product and feed | 26% |

**Figure 2: Screen shot of the feed additive impact screen.**

These economic estimates will change as the parameters of the model are changed (Figure 3). For example, if the product improves feed efficiency by 23%, thus changing the milk/feed ratio from 1.58 to 2.05, the net marginal return above cost increases to $0.0644/cow/day, the net rate of return on product increases to 64%, and the net rate of return on product and feed costs increases to 36%.



Feed Additive Evaluator

| | |
|---|---|
| Milk Revenue $/d/cow | $0.2250 |
| Feed cost due to response | $0.0606 |
| Adjusted Product $/d | $0.1000 |
| Net marginal return above cost | $0.0644 |
| Net Rate of return on product | 64% |
| Net Rate of return on product and feed | 36% |

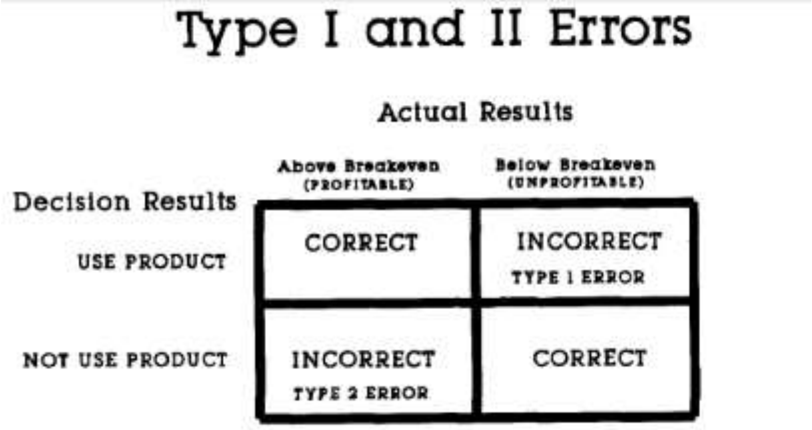
Est. Nel/lb of milk 0.329

Estimated DM Intake (lbs) 50.6

**Figure 3: Screen shot of the feed additive impact screen with an improvement of feed efficiency of 23% (i.e. 23% less feed per lb. of milk response)**

## Type I and II Error Analysis

In addition to changes in the mean response, products also can vary in the variation of response (Galligan, 1991a, b). For a product to be economically competitive, it must not only have a favorable mean response, but its expected value of success should exceed its expected value of failure. A convenient approach to evaluate these dimensions of a product can be done by comparing the expected values of Type I and Type II error associating with using a product (Figure 4). For a product to have a favorable economic response, it must have an impact on milk yield and/or composition (breakeven values), the value of which exceeds the cost of using the product along with any other associated cost (feed intake, cost of implementation). Responses below the breakeven level result in economic losses while those that exceed it will result in positive economic rewards. These concepts can be integrated into the general question facing management, that is, to use or not use a product and evaluating the potential relative cost of management error. A product either works (is above breakeven) or does not work (is below breakeven). If management uses a product and the response is below breakeven, a type I error has been committed. If management fails to use a product and the response if it had been used was above breakeven, a type II error has been committed. The first criterion of evaluation of type I and II error analysis is to make the decision that has the minimum error cost. If type I error is less than type II error, then the product should be used with the rationale being that the cost of potential failure is less than the cost of failing to take advantage of favorable outcomes. Further criteria could be to evaluate the relative magnitude of the errors.



Type I and II Errors

| Decision Results | Actual Results<br>Above Breakeven<br>(PROFITABLE) | Actual Results<br>Below Breakeven<br>(UNPROFITABLE) |
|---|---|---|
| USE PRODUCT | CORRECT | INCORRECT<br>TYPE 1 ERROR |
| NOT USE PRODUCT | INCORRECT<br>TYPE 2 ERROR | CORRECT |

**Figure 4: Decisions and outcome possibilities.**

### Example Calculation

A sample calculation of type I and II error analysis will be done to demonstrate the fundamental concepts using sodium bicarbonate as an example (Galligan et al. 1991a). A summary of the research literature suggests that the mean response to sodium bicarbonate is about 1.4 kg of milk/day per cow fed the product. The variation of this response across trials was estimated to be 1.13 kg (standard deviation). The marginal increase in milk yield was assumed to be associated with an increase in feed intake that was valued at $0.09/kg of milk response. Based on a product cost of $0.05/cow/day, a milk value of $0.26/kg of milk and the above marginal feed cost, a breakeven level of response is estimated to be 0.3 kg/cow/day. These error costs will change if any of the underlying parameters change.

## ■ Stochastic Dominance

When comparing products, one can calculate the cumulative distribution curves of the expected net values for each product and the varying levels of response. Products can be ranked based on position of the curves (1st order stochastic dominance) where curves further to the right have more favorable economic value relative to risk compared to curves to the left. In the example presented, bovine somatotropin (BST) has a much greater profile than sodium bicarbonate or MEGALAC, as reflected by it being further to the right. For situations where the curves cross, one can use the 2nd order of stochastic dominance, where the products are ranked by the area under the cumulative curves and products with the least area are viewed as more favorable. Megalac would rank in the middle based on second order stochastic dominance.

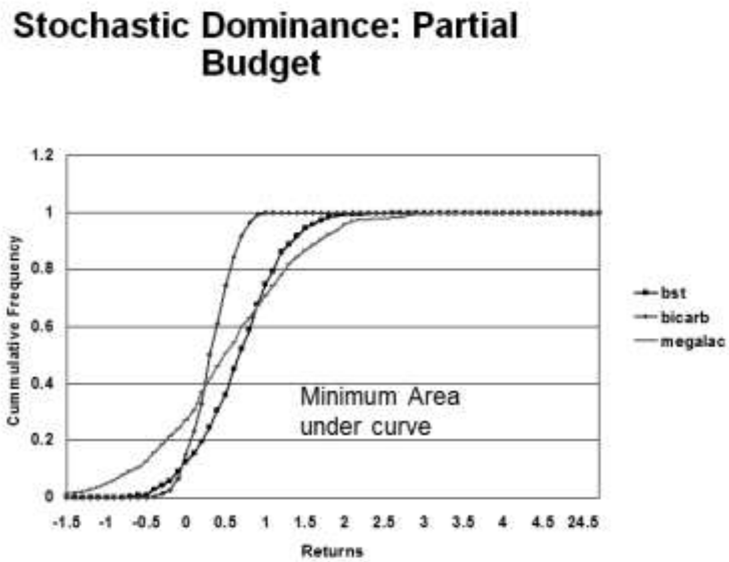
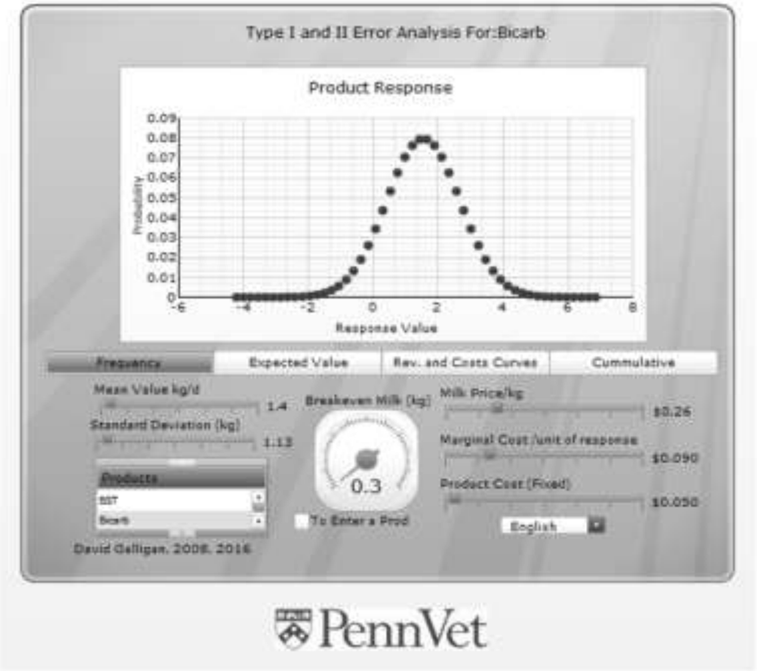


**Figure 5: Cumulative distributions of expected net returns (probability x (revenue-cost)) for 3 products with different means and variations in response.**



Mean Value kg/d 1.4

Standard Deviation (kg) 1.13

Breakeven Milk (kg) 0.3

Milk Price/kg $0.26

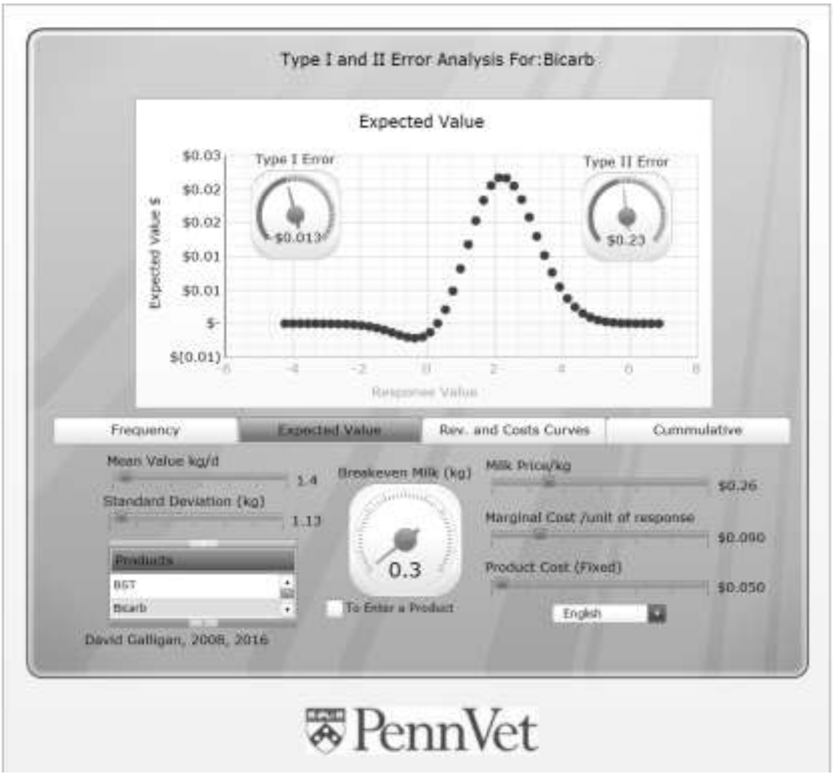
Marginal Cost /unit of response $0.090

Product Cost (Fixed) $0.050

**Figure 6: Screen shot of the Type I and II error analysis dashboard, showing the distribution of milk responses to sodium bicarbonate feed additive.**

The breakeven level of response determines the boundary between a type I and type II error. This boundary level can change if any of the input parameters change. The next attribute of the product to be evaluated is the frequency of these errors and more importantly their expected values. The expected value is the probability of a given level of response occurring (from the distribution curve) multiplied by the net value of the response level (revenues less costs). From the distribution of the response and the breakeven level, the two error costs be can calculated by integrating the expected value area of the distribution below breakeven (type I) and above breakeven (type II).

In Figure 7 the expected value curve for sodium bicarbonate is shown. The inflection point of the curve occurs at the breakeven level (0.3 kg). Type I error, which occurs when the product is used and the response is below breakeven, has an expected value of -$0.013/cow/d. This cost is presented as a negative value to reflect a direct expense. The type II error occurs when management fails to use the product, and yet the response is above breakeven and has an estimated lost opportunity cost of $0.23/cow/day. The absolute value of type I error is much smaller than type II error and thus the appropriate decision would be to use the product and bear the risk that it might not work.



Mean Value kg/d 1.4

Standard Deviation (kg) 1.13

Breakeven Milk (kg) 0.3

Milk Price/kg $0.26

Marginal Cost /unit of response $0.090

Product Cost (Fixed) $0.050

**Figure 7: Screen shot of the expected values of the Type I and II errors.**

## ▪ Option Value of Feed Additive Products

In addition to direct impacts on milk production and feed efficiency, and other elements of economic importance (disease frequency, reproduction, longevity, etc.), some feed additives have another dimension of value that is important in risk management (Galligan, 2002). Let's consider two feed related products, one is given to the cow in its daily ration while the other is added during ensiling. For discussion purposes, let's assume that the products ultimately have the same impact on production (Figure 8, yield and composition), the same variation in response, and are priced so that the daily costs/cow are identical. Based on this information, these products would be valued identically using all the methods described above. However, the product that is fed to the cow daily has an additional dimension of value in that management can immediately remove the product if it does not work (i.e., if the response is below breakeven). This is a type of real option referred to as an abandonment option, and confers additional value to products that have it as an attribute. This requires active management in that management must make the effort to evaluate the response (respond to the resolution of uncertainly) and have the tools to make the evaluation and determine and alternative use of resources. Passive management will not respond to resolved uncertainly and continue to use an inferior product.

**Figure 8: The structure of an abandonment option decision.**

## ▪ Summary

Feed additives can be an important part of the technologies used in the modern dairy to promote economic efficiency. Change in milk yield and composition must be valued relative to the cost of the additive and its implementation. In addition to the cost of the additive, the analysis should include an appropriate accommodation of the associated feed cost due to any changes in feed efficiency associated with the product. Products also have risk characteristics that can be evaluated using type I and II error analysis and further ranked using stochastic dominance principles. Additionally, many products might have additional value in the form of real options such as an abandonment option. This value is realized when good management is actively involved in the management and evaluation of the use of a product.

## ■ References

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