Optimizing Income Over Feed Supplement Costs

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Introduction

Large fluctuations in milk and supplemental feed prices create anxiety and uncertainties. Profit margin may shrink rapidly when milk price goes down and supplemental feed prices go up. Thus, it is important that correct decisions are made to maximize return on supplemental feed expenses. The change in prices and milk production response to feed supplements are especially important because they impact directly the profitability of dairy farms. Supplements might represent the largest portion of expenses and milk is by far the most important revenue generator in a dairy enterprise. Usually, more than 90% of dairy farm revenue comes from the milk check and more than 40% of the expenses are used on purchased feeds. Analyses from surface responses to income over feed cost for different crude protein (CP) levels have been studied in the past (Roffler et al., 1986), but the distinction between rumen undegradable protein (RUP) protein and rumen degradable protein (RDP) creates a need to further fine-tune the formulation of supplements for maximum income over feed cost. Volatile market conditions that are greatly impacting feeds and milk prices require the ability to make strategic ration formulation adjustments promptly and efficiently to maintain dairy margins and remain economically competitive. An interactive simulation model may be beneficial in exploring those strategic decisions in response to fluctuating milk and feed prices.

Justification

Traditional diet formulation is based on finding the least cost ration that provides the minimum level of required nutrients for a desired level of milk production (Tozer, 2000; Howard et al., 1968). Typically, diet formulation does not consider changes in milk production due to changes in CP, RUP and RDP that could be fine-tuned to maximize income over feed supplement costs. Rotz et al. (1999) found that profitability of dairy farms could be improved by decreasing CP intake and adjusting RUP and RDP through a better selection of fed ingredients, which vary according to market prices of feed stuffs. This previous study also found that lower CP diets decrease N excretion and consequently environmental impacts, which has been confirmed by a number of recent publications (Broderick, 2003; Wattiaux and Karg, 2004). Rotz et al. (1999) developed the dairy farm model (DAFOSYM) capable to estimate the income over supplement costs, which nowadays has evolved to the integrated farm system model (IFSM) (Rotz et al., 2007). The IFSM, although very complete, is complex and serves the scientific community more than field-based end-users. In addition, the IFSM model does not perform optimization, but rather simulation of scenarios. This paper main purpose is therefore to present a simple formulation to optimize income over feed supplement costs (IOFSC), implement the formulation in a user-friendly spreadsheet, and perform some case studies.

Maximum IOFSC

As it is usual in many dairy farms, forages produced either on-farm or that are locally available can be considered a fixed proportion in the diet, at least in the short-run. Consequently, the optimization problem can be simplified by discounting the dry matter (DM) and CP provided by fixed amounts of forages from the total needs. The problem to solve then becomes that of optimizing the income over feed supplement costs (IOFSC) given feed supplement costs, milk price and cow's milk production response to dietary CP.

Thus, the objective function is to maximize the IOFSC of a diet formulation:

$$\max(MV - \sum_{i=1}^{N} SV_i) \qquad [1]$$

where MV is the milk value calculated as the milk price (Mp) times the milk production (MP), SV_i is the value of the i supplement defined as the price of the supplement (Sp_i) times the quantity of such supplement (SQ_i) when there are N available supplements in the diet, which need to provide the expected DM or dry matter intake (DMI) under the constraint of an upper limit for RUP, RDP, and CP; Therefore,

$$\sum_{i=1}^{N} = DMI \qquad [2]$$

$$RUP \leq \max RUP, RDP \leq \max RDP, CP \leq \max CP \qquad [3]$$

and the DMI is calculated following NRC (2001, Eq. 1-2),

$DMI = (0.372*FCM+0.0968*BW^{0.75})*(1-e^{(-0.192*((WOL+3.67)))})$ [4]

where *FCM* is fat corrected milk, *BW* is body weight and *WOL* is week on lactation. An initial target *MP* is defined to calculate FCM and from it DMI, however, depending on the selection of supplements, the expected *MP* will change. Therefore final *MP* is calculated using NRC (2001, Pg. 50),

$MP=-55.61+1.15*DMI+8.79*RDP-0.36*RDP^2+1.85*RUP$ [5]

The formulation must include a maximum limit of feed supplements, which are defined by upper maximum levels. The concept of upper levels allow the exclusion of some non-available ingredients (upper limit set at zero) or to put nutritional and biological limits to some ingredients. Therefore,

$SQ_i \leq$ max SQ_i for *i*-1 to *N* for i=1 to N [6]

Supplements can be grouped as those that provide more energy than protein (e.g., corn grain) and those that provide more protein than energy (e.g., soy bean meal). Both type of supplements need to be defined according to their composition of RUP, RDP and CP. Whereas CP is the sum of RUP and RDP, RUP and RDP are influenced by degradability and ruminal disappearance of protein through two simultaneous processes, degradation and passage (NRC, 2001). A fraction "A" is assumed to be instantly degraded, a fraction "C" is assumed to be completely undegradable, and a fraction "B" is assumed to be degradable overtime at a rate of degradation (Kd). Therefore, knowing a constant rate of degradation (Kd) and a rate of passage (Kp), it is possible to calculate the RUP and RDP content of feed stuffs. Research has shown that the rate of passage Kp is dependent on the DMI, BW, feed characteristics, and proportions of forage and supplements in diet. Table 1 provides an example of calculated protein composition for forages and supplements along with their calculated RUP and RDP values.

Table 1. Calculated protein availability of feed stuffs as rumen undegradable protein (RUP), rumen degradable protein (RDP) and crude protein (CP) based on standard values of some forages, energy supplements, and protein supplements.

Feed Stuff	A (%)	B (%)	C (%)	Kd	Kp	Calculated RUP (%)	Calculated RDP (%)	Calculated CP (%)
Forages								
35-Corn silage	51.00	5.62	8.80	4.40	5.93	3.15	5.62	8.80
74-Mixed silage	58.10	34.20	7.70	10.40	5.93	3.82	15.18	19.00
83-Alfalfa silage	57.30	35.30	7.40	12.20	5.93	4.15	17.75	21.90
Energy Supplements								
27-Corn grain	23.90	72.5	3.60	4.90	8.34	4.63	4.77	9.40
8-Barley grain	30.20	61.20	8.60	22.70	8.34	3.11	9.29	12.40
Protein Supplements								
106-Soybean meal	22.50	76.80	0.70	9.40	8.34	18.37	31.53	49.90
25-Corn gluten meal	3.90	90.90	5.20	2.30	8.34	49.69	15.31	65.00
23-Corn distiller grains	28.50	63.30	8.20	3.60	8.34	15.57	14.13	29.70
104-Soybean meal expellers	8.70	91.30	0.00	2.40	8.34	32.83	13.47	46.30

Source: Adapted from NRC (2001, Table 15-1). Code numbers preceding the feed name correspond to NRC codes. Calculated values are based on DMI of 29.26 kg/d for a 625-kg BW cow with an estimated milk production of 50 kg/d.

A Case Study

Consider this situation for a group of Holstein cows with an average of 100 days in lactation producing 36.4 kg (80 lb) milk per day. According to the National Research Council equations, these cows should be consuming on average 24.4 kg (53.66 lb) of DM per day. We can safely assume that 50% of the DMI is provided through forage, which is composed of equal parts of corn silage and alfalfa silage. Therefore, these cows are already receiving 7.7% of CP (1.8% RUP and 5.9% RDP) from the forages. If the target protein in diet is 18% (6.5% RUP and 11.5% RDP), then, the supplements could provide the difference: up to 9.2% CP (4.8% RUP and 5.6% RDP). As previously discussed, supplement sources have different compositions of CP, RUP, and RDP, which not only complete the protein requirements, but also impact milk production. After setting the proportion of forage in the diet to a fixed value, the goal is then to find the combination of supplements that will maximize the IOFSC.

Let's suppose that the group of cows described above currently receives 9.5 kg (20.9 lb) of corn grain and 2.7 (6.0 lb) of soybean meal as supplemental feeds. Under this diet, each cow in this group would have on average $5.20 a day IOFSC using Wisconsin

February 2009 feed and milk prices: $0.207/kg ($9.4/cwt) milk, $0.14/kg ($3.54/bu) corn and $0.33/kg ($300/ton) soybean meal. However, under the same price structure, the IOFSC could be as much as $5.54 a day if the sources and proportions of supplemental feeds are fine-tuned. A $0.34 per cow per day additional IOFSC could be realized if the supplements are 8 kg (17.6 lb) of corn grain, 1.91 kg (4.2 lb) of soybean meal, and 2.27 kg (5 lb) of corn distiller grains at $0.154/kg ($140/ton).

User-Defined Analyses

The actual combination of supplement will vary substantially depending on the availability and costs of feed supplements, and price received for milk. Every situation is different and because of that we have created a user-friendly computerized (PC-based) tool that could help with this task. The IOFSC along with a fact sheet and instructions are freely available at the University of Wisconsin Extension Dairy Management website: http://www.uwex.edu/ces/dairymgt/ under "Management Tools" with title "Income Over Feed Supplement Costs." This Excel spreadsheet tool (Figure 1) uses linear programming to maximize the IOFSC for user-defined parameters (Equations 1 through 6) of cow productive characteristics, availability of supplements, economic parameters, NRC (2001, Table 15-1) nutrient composition of feeds, and calculated RUP, RDP and CP. After finding the optimal IOFSC, the tool could still further assist the user to determine whether a decrease in CP studied by substituting supplements is justified under defined conditions. For convenience, the spreadsheet is divided in 10 successive sections that follow a logical order to understand, analyze, optimize the IOFSC, and substitute feed supplements. User defined data is entered in yellow marked cells and results are seen in blue marked cells, figures and tables. The user selects whether to work on metric or English units, which will be consistent across the spreadsheet.

In *section 1*, the user enters milk production (*MP*), body weight (*BW*) and days in milk (*DIM*) as inputs to calculate dry matter intake (*DMI*). **Example:** The *DMI* of a milking cow producing 41 kg milk/day (90 lb milk/day), weighting 636 kg (1,400 lb), and 180 days in lactation is calculated at 26.3 kg/day (57.9 lb/day). Further, if the user finds that this calculated amount does reflect known conditions, a "spin button" is provided to adjust the calculated amount to desired or known level.

Section 2 lets the user select the sources and proportion of forages in the diet. The application then uses the NRC feed composition table values to calculate CP, RDP, and RUP provided by the forage

sources. **Example:** A diet containing 50% of forage, of which 50% is corn silage and 50% is alfalfa silage will provide 2.0 kg of CP (4.4 lb) or 7.7% CP of the diet (1.8% RUP and 5.9% RDP).

In *sections 3 & 4*, the user defines up to 3 supplemental energy feed stuffs: corn, barley, and wheat; and up to 8 supplemental protein feed stuffs: soybean meal, corn gluten meal, corn gluten feed, corn distiller, whole soybeans, soybean meal expellers, blood meal, and urea. Furthermore, the user needs to define the price and the upper limit (maximum per day per cow) for each one of the feed supplements. Supplements can be excluded from the optimization by either entering zero or leaving a blank in the corresponding upper limit cell. The user can enter the amounts of supplements in the current diet as an option. If this is done, the spreadsheet will provide a comparison of the IOFSC for the current diet to the optimized one. **Example:** As shown the user can set the price ($/bu) and the upper limit (lb) of the energy supplements to: corn (4 & 15) and wheat (7.4 & 10); the price ($/ton) and the upper limit (lb) of the protein supplements to: soybean meal (250 & 15), corn gluten meal (550 & 2), corn gluten feed (160 & 10), corn distiller grains (200 & 10), soybean meal expellers (402 & 15), blood meal ring dried (900 & 1), and urea (635 & 1). Optionally, the user can set up the amount of these ingredients currently in the diet such as (lb): corn grain (10), wheat (1.5), soybean meal (5), corn gluten feed (5) and corn distiller grains (5).

Table 2. Exemplified prices, upper limits and current amounts used to perform analyses with the Income Over Feed Supplement Costs application.

Feed Stuff	Price		Upper Limit		Current in Diet	
Energy Supplements	$/kg	$/bu	kg	lb	kg	lb
27-Corn grain	0.16	4.0	6.81	15	4.54	10
Wheat grain	0.27	7.4	4.54	10	0.68	1.5
Protein Supplements	$/kg	$/ton	kg	lb	kg	lb
106-Soybean meal	0.28	250	6.81	15	2.27	5
25-Corn gluten meal	0.61	550	0.91	2		
24-Corn gluten feed	0.18	160	4.54	10	2.27	5
23-Corn distiller grains	0.22	200	4.54	10	2.27	5
104-Soybean meal expellers	0.20	402	6.81	15		
14-Blood meal ring dried	0.99	900	0.45	1		
Urea	0.70	635	0.45	1		

In *section 5*, the user sets an upper limit for dietary RUP and RDP and enters an appropriate milk price. **Example:** The upper limit for RUP and RDP are set to 6.5 and 11.5%, respectively, and the price of milk to $16/cwt.

Section 6 is where the user performs the optimization analysis by just clicking the "Maximize IOFSC" button (Figure 1) to perform a maximization that will

calculate the amount of each selected supplemental feed to maximize IOFSC. **Example:** The maximum IOFSC for the working case is $11.64/cow/day producing 40.0 kg (88.32 lb) of milk/day using 5.22 kg (11.5 lb) of corn, 0.17 kg (0.38 lb) of corn gluten meal, 3.2 kg (7.0 lb) of corn gluten feed, and 4.54 kg (10 lb) of corn distiller grains. Using the current diet, the IOFSC is calculated to be $11.06/cow/day ($0.58 lower than optimal), producing 38.25 kg (84.26 lb) of milk/day.

Once the user has the optimized quantities of supplemented feed, the spreadsheet in *sections 7 to 10* allows analyzing the impacts of substituting feed supplements and performing sensitivity analyses of price change. Before performing a substitution analysis though, additional information is needed.

Figure 1. Income Over Feed Supplement Cost (IOFSC) application. Sections pertaining to maximization of the IOFSC.

The user needs to define in section 7 the two feed supplements to be dynamically substituted and a potential price range of change of the energy supplement, the protein supplement, or the milk.
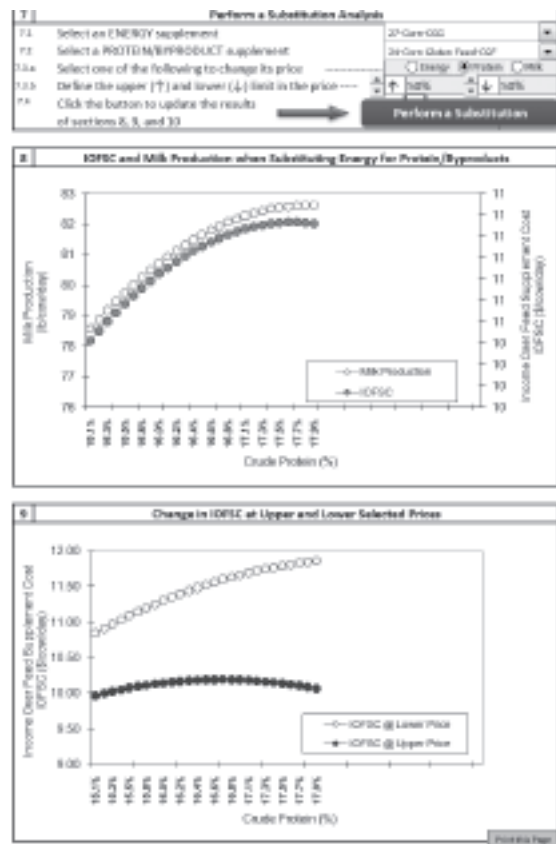

Figure 2. Figure 1. Income Over Feed Supplement Cost (IOFSC) application. Sections pertaining to perform substitution analyses.

Once these are defined, the substitution analysis can be performed by just clicking the "Perform Substitution" button (Figure 2). Results are displayed as figures and a table in *sections 8 to 10*. **Example:** Graph in *section 8* (Figure 2) displays the sensitivity of milk production and IOFSC in response to a change in dietary CP (DM basis) as a result of substituting corn grain ($4/bu) for corn gluten feed ($160/ton) when milk price is $16/cwt. This graph shows that milk production continues to increase as dietary CP increases above 17.5%, while the IOFSC reaches a plateau and even decreases.

The example discussed shows that feeding more than 17.5% CP may result in higher milk yield, but without additional net income. Graph in *section 9* (Figure 2) displays the sensitivity of IOFSC in response to a change in dietary CP (DM basis) as a result of substituting corn grain for corn gluten feed when corn gluten feed price is $240/ton (50% above regular price, upper price) and when corn gluten feed price is $80/ton (50% below regular price, lower price). Compared with graph in *section 8*, the IOFSC in response to the substitution of corn grain for corn gluten feed reaches a plateau earlier when corn gluten feed price is high ($240/ton) and later when

corn gluten feed price is low ($120/ton). Consequently, lower CP levels may be justified when the price of corn gluten feed is high. *Section 10* (not shown in Figure 2) displays the tabular data of graphs presented in *sections 8 and 9*.

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Appendix: Fact Sheet and Instructions of Use for Income Over Feed Supplement Costs (IOFSC)

The Income Over Feed Supplement Cost (IOFSC) is an Excel application (PC-based) that needs to be installed in a user local machine:

1. Install the IOFSC application

1.1. Prepare Excel
 Open a clean copy of Excel on your computer
 Excel 2003: a) Tools/Macro/Security... Select Low Security level
      b) Tools/Add-Ins... if not checked, check Solver Add-in, then OK
      c) Tools/Solver (make sure solver opens in your spreadsheet)
      d) close Solver. Your Excel 2003 is ready.
 Excel 2007: a) Ribbon (upper left corner)/Excel options
      b) Trust Center/Trust Center Settings/Macro Settings/
      c) Select Enable all macros, then OK
      d) Add-Ins/ Manage: Excel Add-Ins Go...
      e) If not checked, check Solver Add-in, then OK
      f) Add-Ins/Solver (make sure solver opens in your spreadsheet)
      g) Close Solver. Your Excel 2007 is ready.

1.2. Download and extract the application from the Dairy Management Website
 a) Open a Web browser and visit the dairy management website at: http://www.uwex.edu/ces/dairymgt/.
 b) Select Management Tools on the left menu
 c) Under the title Income Over Feed Supplement Cost, click on IOFSC.exe File
 d) Save the executable file in a known location in the local machine
 e) Double click in the file IOFSC.exe saved, select Run
 f) In the WinZip Self Extractor window, the driver "C:" will appear as default, but the user could click on the Browse button to save the files in any other directory. Click Unzip and a message will appear: "4 files were extracted successfully." Click OK.
 g) Locate the folder where the files were extracted. Open folder and open the file with name: IOFSC.xls.
 h) For Excel 2003 users: In the event that a Security Warning window appears asking to Disable or Enable Macros, select to Enable Macros.
 i) For Excel 2007 users: In the event that a Security Warning appears in the top of the spreadsheet, click on the Options... button provided by this warning, select Enable this content and click OK.
 j) Congratulations: the application is ready to be used, continue below.

2. Work with the IOFSC

2.1. General recommendations
 a) Notice that the spreadsheet is divided in 10 sections
 b) In each section, cells marked in yellow are input data that can be overwritten as desired. Drop box menus and option button selections are also for personal choice. Cells in blue are output data where results are displayed, but the user is not allowed to change because they may include formulae.
 c) The large blue button in Section 6 labeled "Maximize IOFSC" and the large red button in Section 7 labeled "Perform a Substitution" are "action∏ buttons that will perform the analysis after data entry is completed.
 e) At the end of each printable page there is a gray button labeled "Print this Page." By clicking on them the user will prompt the printing of the specified page. Each page is formatted to print in a letter size (8" x 11") paper of sheet.