Iranian Journal of Applied Animal Science

Formulation of Least-Cost Dairy Ration for Small-Scale Dairy Farms Using 'Solver Add-Ins' in Microsoft Excel

Research Article

M.E. Hossain[1*], G.B. Das[1] and M.A. Akbar[2]

[1] Department of Animal Science and Nutrition, Faculty of Veterinary Medicine, Chittagong Veterinary and Animal Science University, Khulshi, Chittagong, Bangladesh
[2] Department of Animal Nutrition, Faculty of Animal Husbandry, Bangladesh Agricultural University, Mymensingh, Bangladesh

Received on: 1 Aug 2014
Revised on: 14 Jan 2015
Accepted on: 31 Jan 2015
Online Published on: Sep 2015

*Correspondence E-mail: me.hossain-dasn@cvasu.ac.bd

Online version is available on: www.ijas.ir

ABSTRACT

Small-scale dairy farming in Bangladesh is constrained mostly due to acute shortage, high price and seasonal fluctuation of energy and protein supplements. Poor economic conditions of dairy farmers do not allow them to purchase adequate conventional energy and protein supplements. Locally available non-conventional energy and protein sources can be used as alternatives, cheaper than conventional energy and protein sources. Non-conventional feedstuffs are deficient in certain macro and micro nutrients. As a result, formulation of a least-cost balanced ration using non-conventional feedstuffs is a major challenge for marginal farmers. The current study presents a least-cost formulation plan for the small-scale dairy farmers using locally available low-cost non-conventional feedstuffs. A simple Microsoft Excel program with 'Solver Add-ins' has been used to formulate least-cost rations for crossbred and indigenous dairy cows. The step by step logical procedure ensured that the ration was balanced for most of the key nutrients, was least-cost and gave the user significant control over the formulation process. Incorporation of multipurpose low cost neglected forages such as water hyacinth (*Eichhornia crassipes*), helencha (*Enhydra fluctuans*), ipil-ipil (*Leucaena leucocephala*) and their subsequent effect on cost minimization is discussed. This formulation method may be recommended for use by small-scale dairy farmers as well as livestock extension workers who wish to formulate least-cost dairy rations using locally available feed sources to optimize the feeding of dairy animals at farm level.

KEY WORDS dairy, least-cost, non-conventional, ration, small-scale farm.

INTRODUCTION

Feeding is one of the most important factors affecting the profitability of a dairy enterprise (Goswami *et al.* 2013). Therefore, the economics of feeding is a major concern for dairy farmers' decision making. Feed accounts around 60-80% of the variable costs of milk production (Webster, 1993; Patil, 2010). Cost-effective feeding of dairy cows is relatively complex since there is no scope to compromise feed price with cow health and milk production. The major nutrients to be supplied in a feeding program include energy, protein, minerals and vitamins (Pond *et al.* 1995). Carbohydrates are the major source of energy in dairy rations. Carbohydrates are supplied as forages, non-legume cereal grains and their milling by-products. Protein is included in the dairy concentrate mix as soybean cake, mustard oil cake and til (sesame) oil cake and meat and bone meal. Minerals and vitamins are incorporated as pre-mixes. The composition of cows' ration is usually decided based on the dry matter intake required for a required milk production. However, due to the high cost and non-availability of energy and protein sources, locally available supplements are required to feed dairy cows optimally. These feedstuffs should be supplied in higher quantities as a replacement to expensive concentrates to reduce feed costs. However, there is a problem of formulating diets with ingredients that are unbalanced with respect to protein, energy, vitamins and minerals and at the same time that vary in cost. There are several possibilities for utilizing non-conventional feeds in solving nutritional problems. The most common is least-cost ration optimization based on linear programming which has been widely used in modeling the least-cost ration (O'Coner *et al.* 1989; Munford, 1996; Alexander *et al.* 2006; Chakeredza *et al.* 2008). However, the easiest is the microsoft excel spreadsheet program using 'Solver Add-ins'. No systematic study has so far been reported from Bangladesh to formulate least-cost rations for dairy cows using the 'Solver' function. Therefore, the present study aimed to formulate least-cost dairy rations using Excel in English for Bangladeshi dairy farmers,

MATERIALS AND METHODS

Study area

The study was carried out in 12 different small-scale dairy farms located in the peri-urban and urban areas of Chittagong, Bangladesh. Farms holding at least 20 Holstein Friesian dairy cows were studied. The following dairy farms were selected: Azizia Dairy Farm, Bhuyian Dairy Farm, Janata Dairy Farm, Jane Alam Dairy Farm, Jarif Dairy Farm, Liza Dairy Farm, Belal Dairy Farm, Mollah Dairy Farm, Rajabadsha Dairy Farm, Samia Dairy Farm, Bandhan Dairy Farm and Mainuddin Dairy Farm.

Studied animals

Crossbred Holstein Friesian milking cows weighing 250-400 kg in mid-late lactation were studied. A total of 240 multiparous dairy cows between their 2^{nd} and 3^{rd} calving were studied from 12 small-scale dairy farms. 120/240 cows were selected at random. Dry cows, primiparous cows and multiparous cows in early lactation were rejected because in early lactation, nutrients are mobilized very fast from body to milk which masks the influence of diet. All animals were reared under an intensive system. Animals were offered green fodders *ad libitum* and concentrates at the rate of 0.5 kg per liter of produced milk.

Selection of ingredients

Conventional and non-conventional ingredients were selected according to their availability, cost, palatability, chemical composition and digestibility. Rice straw (*Oryza sativa*), napier (*Pennisetum purpureum*), German (*Echinochloa polystachya*), para (*Brachiaria mutica*), water hyacinth (*Eichhornia crassipes*), helencha (*Enhydra fluctuans*), mander leaf (*Erythrina Indica*), ipil-ipil leaf (*Leucaena leucocephala*), maize (*Zea mays*), wheat, wheat bran, broken rice, rice polish, molasses, soybean meal (*Glycine max*), meat and bone meal, mustard oil cake, til (sesame, *Sesamum indicum*) oil cake, bone meal and dicalcium phosphate were selected as the major ingredients.

Database

Ingredients, their cost and chemical composition were listed as a database. The database can be modified at any time and more feed ingredients can be added when they become available. A reference database has been shown in Table 1. For simplicity, only five parameters are shown: metabolizable energy (ME), crude protein (CP), Ca, P and price.

Specification of diet

The required feed quality was specified. Data on the nutrient requirements of dairy cattle varying in weights and milk production has been given in excel spreadsheet as a constraint factor (Table 2). Usually livestock feeds are balanced for energy, protein and some of the macro minerals. Some vitamins and minerals need to be incorporated as premixes. For simplicity, here we formulated a dairy concentrate mixture containing 12 MJ ME/kg, 18% CP, 1% Ca and 0.5 % P. This mixture is suitable for cows in mid-lactation (Dunham, 1989).

Construction of formulae

Formulae for calculating ME, CP, Ca and P in the feed were specified. Microsoft excel formulae began with an equal (=) symbol in the target cell. The results of the formula appeared in the worksheet while clicked in the formula bar or written there manually. It is important to use cell references in formulae whenever possible. When one needs to include a cell reference in a formula, it often is easier to point to the cell than it is to type in the cell reference. Using a pointing method may help avoid typing mistakes. The following steps were followed in formula construction:

1) the cell was selected where the answer was expected to appear.
2) An= (equal symbol) was typed to begin the formula.
3) to use a cell reference, it was clicked with the mouse.
4) a marquee (flashing set of dotted lines) appeared around the cell.
5) the reference appeared in the cell where the formula was built.
6) formula or arithmetic operators were typed and continued
7) ENTER was pressed to complete the formula.
8) the result of the formula was displayed in the worksheet
9) the respective formula appeared in the formula bar immediately.

Table 1 Chemical composition of feed ingredients used for least-cost ration formulation

Ingredients	ME (MJ/kg)	CP (%)	Ca (%)	P (%)	Price (BDT/kg)
Maize	**12.5**	9.2	0.1	0.4	20.0
Wheat bran	4.1	13.8	0.1	1.2	25.0
Rice polish	11.1	11.9	0.4	1.2	15.0
Molasses	9.0	2.8	1.5	0.7	25.0
Soybean meal	**8.4**	45.0	0.3	0.7	27.0
Til oil cake	9.1	37.0	2.9	1.3	20.0
Mustard oil cake	8.3	35.0	0.9	1.2	20.0
Gram chuni	8.7	28.2	1.3	1.3	24.0
Meat and bone meal	7.9	53.8	11.3	5.4	25.0
Dicalcium phosphate	0.0	0.0	24.3	18.2	20.0
Bone meal	0.0	0.0	27.6	11.9	20.0
Para grass	10.0	12.0	0.3	0.2	3.0
German grass	10.0	9.7	0.3	0.2	3.0
Napier grass	10.0	10.2	0.4	0.3	3.0
Dal grass	10.0	7.5	0.3	0.2	3.0
Roadside grass	10.0	8.9	0.3	0.3	3.0
Maize plant	10.0	7.2	0.3	0.2	3.0
Black gram	9.0	13.0	0.5	0.4	4.0
Water hyacinth	9.0	9.8	0.3	0.3	2.0
Helencha	**9.0**	**14.0**	0.5	0.4	2.0
Ipil ipil tree leaf	10.0	23.3	0.8	0.7	3.0
Jackfruit tree leaf	9.0	15.6	0.6	0.4	3.0
Banana tree leaf	9.0	12.5	0.4	0.4	3.0
Bamboo leaf	9.0	12.0	0.4	0.3	3.0
Rice straw	9.0	3.1	0.1	0.1	1.0

Table 2 Dairy ration using conventional feed ingredients

Target cell (min)					
Cell	**Name**	**Original value**		**Final value**	
K27	Total price	0.0		12.4	
Adjustable cells					
Cell	**Name**	**Original value**		**Final value**	
B2	Maize (kg)	0.00		17.95	
B3	Wheat bran (kg)	0.00		0.00	
B4	Rice polish (kg)	0.00		12.55	
B5	Molasses (kg)	0.00		0.00	
B6	Soybean meal (kg)	0.00		18.13	
B11	Dicalcium phosphate (kg)	0.00		2.97	
B12	Bone meal (kg)	0.00		0.00	
B14	German grass (kg)	0.00		48.40	
B26	Rice straw (kg)	0.00		0.00	
Constraints					
Cell	**Name**	**Cell value**	**Formula**	**Status**	**Slack**
B27	Total feed (kg)	100.0	B27=100	Not binding	0
C27	Total metabolizable energy (MJ)	10.0	C27=10	Not binding	0
E27	Total crude protein (kg)	16.0	E27=16	Not binding	0
G27	Total Ca (kg)	1.0	G27=1	Not binding	0
I27	Total P (kg)	1.0	I27=1	Not binding	0

Five formulae were constructed to calculate total weight (kg), ME (kcal/kg) CP (g/100 g), Ca (g/100 g), P (g/100 g) and price BDT/kg)

1. Total amount (kg)= SUM(B2:B26)
2. ME (MJ/kg)= SUM(C2:C26) / 100
3. CP (%)= SUM(E2:E26) / 100
4. Ca (%)= SUM(G2:G26) / 100
5. P (%)= SUM(I2:I26) / 100
6. Price (per kg)= SUM(K2:K26) / 100

Running 'Solver Add-ins'

The 'Solver' function must be available in the menu bar under 'Data' in Microsoft Excel 2007. If not available, the user should go to 'Office button' at the extreme top left corner, click on 'Excel option' at the bottom, select 'Add-ins' and press 'Go'. The user should check 'Solver' then press OK to activate itbefore proceeding (Figure 1). If 'Solver' is not available in the 'Add-ins' list, the original CD from which Excel was installed may be required to re-install it.

Once 'Solver' is available, the user is ready to formulate least-cost ration. The 'Solver' parameter dialog box has an 'Option' button which allows access to a submenu where the "use automatic scaling" and "assume non-negative" options should be checked (Figure 2). Pressing "OK" in the 'Solver' options dialog box returns the user to the previous menu which allows the formulationto be completed. The cost/kg (F10) is selected as the target cell and is set to seek minimum value.

Feeding programme

It has been recommended that a cow should be allowed 0.4 kg concentrate dry matter per kg of milk production if milk yield is less than 15 kg/day (Dunham, 1989). The assumption is that as per ARC (1980) the requirement of ME (kcal/kg) per kg milk production is 5.25 MJ. Since the concentrate mixture contains 11.0 MJ ME/kg, therefore, 0.4 kg concentrate mixture is required per kg milk production. It was also assumed that the forage part of the diet will fulfill the maintenance requirements provided total dry matter will be supplied at the rate of at least 3% of live weight. The whole feeding program was maintained as per determining requirement of total nutrients, requirement of total of green forage, requirement of total of dry forage, requirement of total vitamin-mineral premix, ratio of roughage: concentrate and Ca:P.

RESULTS AND DISCUSSION

Nutrient restrictions

In present study, two types of restrictions were used: 'Equal to' restriction and 'Smaller than or equal to' restriction to optimize nutrient density in the formulated ration.

'Equal to' restriction

Using 'Solver Add-ins' 'an 'equal to' restriction was applied to total dry matter, ME (kcal/kg), CP (g/100 g), Ca (g/100 g) and P (g/100 g).

The dry matter restrictions were imposed separately for roughages and concentrate to fit the ration of roughage: concentrate for the lactating animals at specified levels of milk production. By imposing specific restriction, it was made sure that the least cost formulation maintained desired proportion of nutrients.

Smaller than or equal to restriction

Equal to restriction was applied to Napier, German, Para, Water hyacinth, Mander leaf, Ipil-ipil leaf, Maize, Wheat, Wheat bran, Broken rice, Rice polish, Molasses, Soybean meal, Meat and bone meal, mustard oil cake, til oil cake and Dicalcium phosphate.

Setting values

Values for straws, forages, concentrates and mineral supplements were set based on purchase values in the selected locality. Later they were simulated with on-farm production values. For concentrate, in both cases the values were similar.

Input coefficients

The specified nutrients of the selected ingredients particularly dry matter, ME, CP, Ca, and P in different feeds and fodders were obtained by analyzing them directly in the Animal Nutrition Laboratory, Chittagong Veterinary and Animal Science University, Khulshi, Chittagong-4225, Bangladesh (AOAC 1994).

Dairy feed formulation constitutes approximately 60-80% of variable costs (Webster, 1993). The most critical nutrients to balance for ration formulation include energy, protein, minerals and vitamins (Pond *et al*. 1995).

These nutrients are already available to a variable extent in low-cost non-conventional roughages as well as in concentrates.

Therefore, it is necessary to balance them mathematically while minimizing cost. Smallholder farmers have a wide range of locally- available feed resources (Chakeredza, 2008).

The major problem, however, facing smallholder dairy farmers under current circumstances is how to optimize different ingredients into the feed mix at least cost. This paper describes an easy process using Microsoft Excel to achieve this objective.

The advanced spreadsheet programme proceeds following a database of locally-available conventional and non-conventional feed ingredients (Table 1), their chemical composition, inclusion level and cost; defining requirements; constructing equations and finally computing the diet use the 'Solver' function in Excel. The programme has been advanced by several workers (Pesti and Seila, 1999; Thomson and Nolan, 2001) for ration formulation. Its use requires a simple installation of Microsoft Excel with 'Solver Add-ins'. The farmers, however, need to know only chemical composition, inclusion level and cost of different feed ingredients and the requirements of animals of different age, sex, purpose and level of productivity under varied environmental conditions and systems of production to formulate rations. In the optimum plans shown here, high-cost concentrates are partially replaced by non-conventional forages.

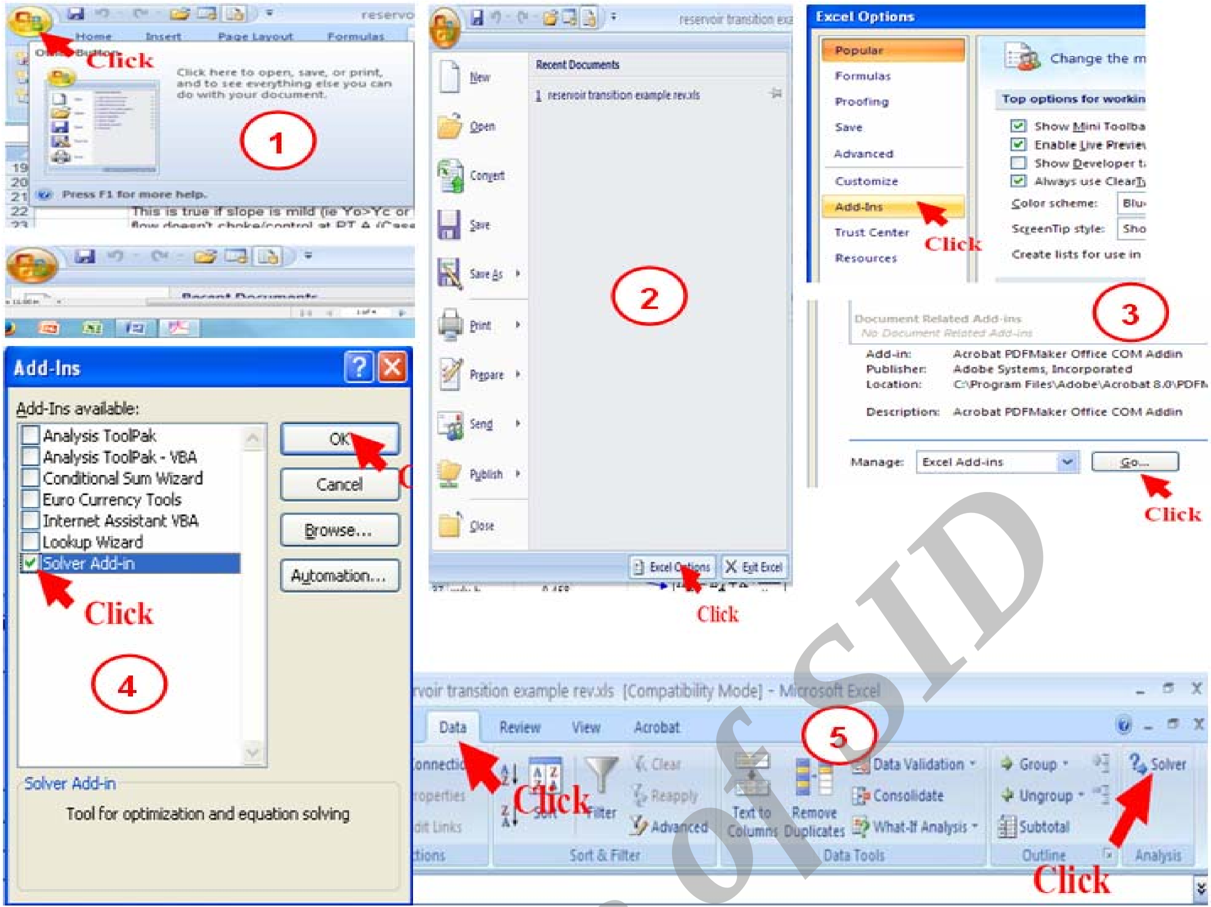

Figure 1 Step by step procedure to generate 'Solver' function

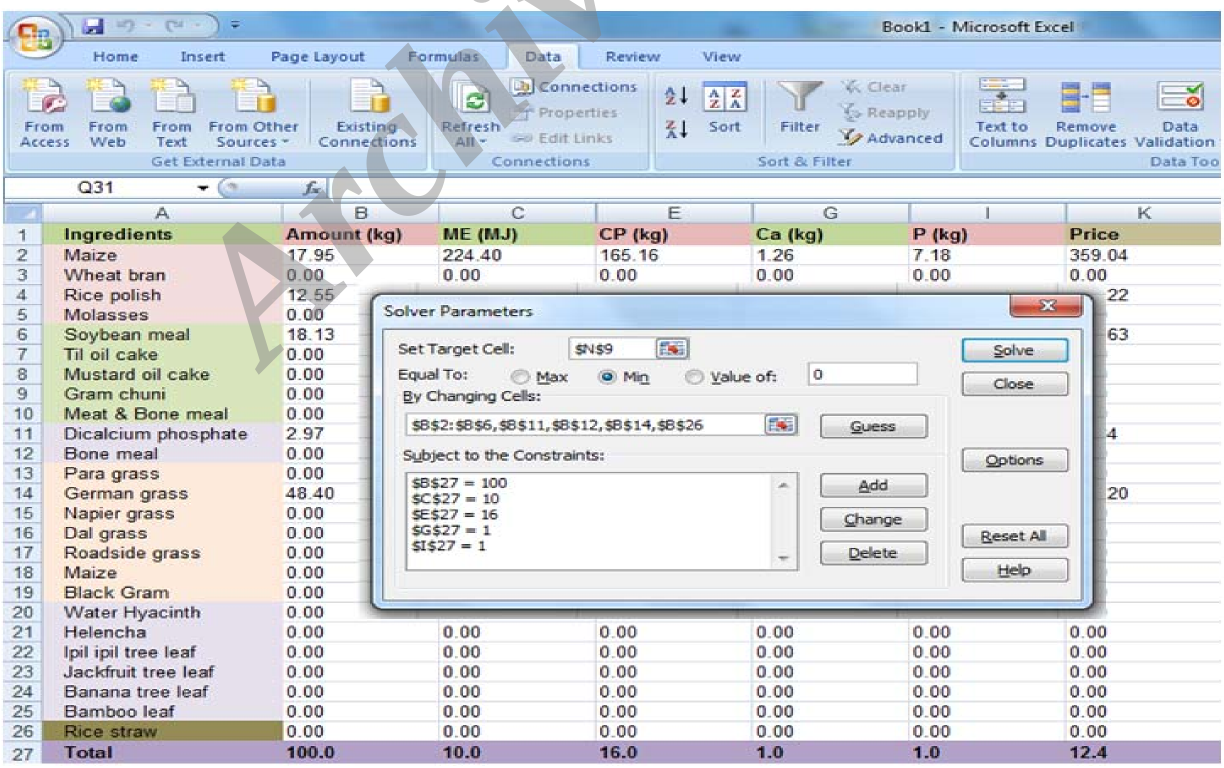

Figure 2 'Solver' function menu bar showing option button

Relatively abundant forages are included in the final plan mainly because of their seasonally high production with low cost, high dry-matter production, reasonably good fodder quality, drought tolerance and persistence under frequent harvesting, thereby reducing the per unit feed cost while providing essential nutrients required for increased milk production. The incorporation of soybean meal into that conventional plan substantially increased feed cost. Therefore, soybean meal was substituted with meat and bone meal which decreased feed cost and gave a balanced amino acid picture for least-cost feed formulation (FAO, 2004).

Rice is the staple food for Bangladeshi people and rice straw is the most abundant crop residue for cattle. Rice straw may provide sufficient dry matter to dairy cows at very low cost. Straw can provide neutral detergent fiber, acid detergent fiber and crude protein. Despite their high prices, wheat bran and molasses were included in the optimum plan shown here since they provide more total digestible nutrients. However, an increase in cost due to increased quantities of German grass, maize, rice polish and soybean meal was compensated by the inclusion of low-cost locally-available til oil cake, meat and bone meal and helencha.

Incorporation of mineral mixture in the optimum plan shown here was essential to provide Ca, P, Na, Cl, K, S and Mg which are important for milk production. Additionally, dairy cows are more likely to suffer from deficiencies in Ca and P than in other minerals.

Rice polish, green forages and rice straw were supplied mainly for energy; til oil cake and meat and bone meal provided protein mixtures to the optimal diet at least cost. Cost reduction to the extent of 19.0- 23.0% is noticed elsewhere (Goswami *et al*. 2013) of the world in the optimum plans for crossbred and local cows as compared to the existing plans. The least-cost feeding plan once formulated will continue for a reasonably long time as there are no frequent changes in price of the ration items, so that dairy farmers will continue the same feeding plan. The model may play a reasonably good job as the feed ingredients included in the least-cost plan are not new to the farmers and they are already used in existing feeding plans. However, intensive studies are needed on the effect of using more non-conventional forages in production rations for reducing feed cost.

In the present study, the cost of formulated total mixed ration (TMR) was 12.40 BDT per kg using conventional feed ingredients. The TMR contained 10 MJ ME/kg, CP= 16.0%, Ca= 1.0% and P= 1.0%. However, while the TMR was prepared with unconventional feed ingredients then the cost was only 11.60 BDT per kg (Table 3). So, the gross reduction of feed cost was 8.35%. The method presented in this paper is user-friendly. The user has full control over the whole formulation process. The user can choose any ingredient to work with, change their chemical composition, fix their inclusion levels, modify the ingredient costs depending on market prices, select desired requirements for macro and micro nutrients depending on prevailing circumstance.

Table 3 Least-cost dairy ration using non-conventional feed ingredients

Target cell (min)					
Cell	**Name**	**Original value**		**Final value**	
K27	Total Price	11.6		11.6	
Adjustable cells					
Cell	**Name**	**Original value**		**Final value**	
B2	Maize (kg)	0.00		0.00	
B4	Rice polish (kg)	44.19		44.19	
B5	Molasses (kg)	0.00		0.00	
B7	Til oil cake (kg)	12.22		12.22	
B8	Mustard oil cake (kg)	0.00		0.00	
B10	Meat and bone meal (kg)	3.02		3.02	
B11	Dicalcium phosphate (kg)	0.00		0.00	
B12	Bone meal (kg)	0.00		0.00	
B14	German grass (kg)	25.10		25.10	
B20	Water hyacinth (kg)	0.00		0.00	
B21	Helencha (kg)	12.24		12.24	
B26	Rice straw (kg)	0.00		0.00	
Constraints					
Cell	**Name**	**Cell value**	**Formula**	**Status**	**Slack**
B27	Total feed (kg)	100.0	B27=100	Not binding	5.68195E-06
C27	Total metabolizable (MJ)	10.0	C27=10	Not binding	0
E27	Total crude protein (kg)	16.0	E27=16	Not binding	0
G27	Total Ca (kg)	1.0	G27=1	Not binding	0
I27	Total P (kg)	1.0	I27=1	Not binding	0

Farmers may carry out the formulation as many times as necessary depending on the feed ingredients available. This is a good advantage over the pre-programmed software packages which do not compromise flexibility and give the user limited control over the formulation process.

The program is especially suitable for extension workers working with smallholder dairy farmers who wish to use a wide range of ingredients available on-farm suitable for home mix. During formulation, even if 'Solver' does not give a good solution in the first instance, through the process of iteration it will give the next best formulation which will be much better than "guesstimates" (Chakeredza, 2008).

CONCLUSION

Commercially-available ready-mix feeds are expensive and smallholder dairy farmers do not have authority to manipulate them as per requirements. In developing countries, farmers have a wide number of locally-available cheap but potentially nutritious feedstuffs that can be incorporated in home-mixing. Excel spreadsheets through the use of the 'Solver' function can easily be adapted for farmers or extension workers to compute diets that are balanced for most of the key nutrients. The optimal plan showed how locally-available cheap ingredients can be combined to formulate least-cost rations. The results suggested considerable scope for the reduction of feed cost under given situations and restrictions, while supplying all required nutrients. Therefore, in developing countries under severe resource scarcities at farm level, the formulation and adoption of least-cost plans may help sustainable dairy farming.

ACKNOWLEDGEMENT

The authors acknowledge University Grants Commission (UGC), Bangladesh for financial support and Animal Nutrition Laboratory, Chittagong Veterinary and Animal Science University for technical support.

REFERENCES

Alexander D.L.J., Morel P.C.H. and Wood G.R. (2006). Feeding strategies for maximizing gross margin in pig production. Pp. 33-43 in Global Optimization: Scientific and Engineering Case Studies. United State: Springer US.

AOAC. (1994). Official Methods of Analysis. 15th Ed. Association of Official Analytical Chemists, Arlington, VA, USA.

ARC. (1984). The nutrient requirement of ruminant livestock. Supplement No. 1. Commonwealth Agricultural Bureaux, Farnham Royal, England.

Chakeredza S., Akinnifegi F.K., Ajayi O.C., Sileshi G., Mngoba S. and Gondwe M.T. (2008). A simple method for formulating least cost diet for small holder dairy production in Sub-Saharan Africa. *African J. Biotechnol*. **7,** 2925-2933.

Dunham R.J. (1989). Feeding Dairy Cows. Cooperative Extension Service. Kansas State University, Manhattan. US. Available at: http://www.oznet.ksu.edu/library/lvstk2/mf754.pdf.

FAO. (2004). Food and Agriculture Organization of the United Nations the State of Food Insecurity in the World.

Goswami S.N., Chaturvedi A., Chatterji S., Patil N.G., Sen T.K., Hajare T.N. and Gawande R.S. (2013). Least cost diet plan of cows for small dairy farmers of Central India. *African J. Agric. Biotechnol*. **8**, 5989-5995.

Munford A.G. (1996). The use of iterative linear programming in practical applications of animal diet formulation. *Math. Comput. Simul.* **42,** 255-261.

O'Coner J., Sniffen C.J., Fox D.G. and Miligan R.A. (1989). Least cost dairy cattle ration formulation model based on the degradable protein system. *J. Dairy Sci*. **72,** 2733-2745.

Patil V. (2010). Cost of milk production: A case study of Maharashtra. Available in: www. afcindia. org. in /aug/2010/ 33-25.pdf.

Pesti G.M. and Seila A.F. (1999). The use of an electronic spreadsheet to solve linear and non-linear "stochastic" feed formulation problems. *J. Appl. Poult. Res.* **8,** 110-121.

Pond W.G., Church D.C. and Pond K.R. (1995). Basic Animal Nutrition and Feeding. John Wiley and Sons, Inc, Somerset, New Jersey, USA.

Thomson E. and Nolan J. (2001). UNEForm: A powerful feed formulation spreadsheet suitable for teaching or on-farm formulation. *Anim. Feed Sci. Technol*. **91,** 233-240.

Webster A.J.F. (1993). Understanding the Dairy Cow. Blackwell Scientific Publications, Oxford.