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"Feed Assist"- An Expert System on Balanced Feeding for Dairy Animals

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Abstract

Inadequate feeding is the major factor for low livestock productivity in India. In dairying, feed cost is a major input and feeding practices has to be improved to ensure profits. Still the small scale farmers are following traditional feeding practices and fail to address the complexities involved in ration formulation. To address the complexities in ration balancing based on the nutrient requirements for different categories of livestock, nutrient composition of wide range of feed resources and the cost - a number of expert systems have been developed. However existing expert systems have not been widely used by majority of small farmers due to lack of awareness, access and basic skills required to operate. To address these limitations, "Feed Assist" a farmer friendly expert system for balanced feeding of dairy animals at least cost has been developed using linear programming. "Feed Assist" does not require much expertise to operate and enables the farmers to formulate least cost rations for different categories of livestock using locally available feed resources.

Keywords

Feed formulation, Least cost, Optimization, Balance feeding, Expert system, Mobile apps.

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Introduction

Livestock sector is an important sub-sector of the agriculture of Indian economy and contributes to 4% of the National Gross Domestic Product (GDP) and 25% of agricultural GDP. Distribution of livestock is more even than land in India where small, marginal and landless farmers account for 88% of the livestock ownership and produce most of the milk. Feeding practices for dairy animals in India are mostly traditional relying heavily on crop residues and byproducts mainly bran, pulse husk and oilcakes produced locally (Badve, 1991) and are more often opportunistic considering the availability and cost. Field surveys to assess the adequacy of traditional feeding practices in dairy cattle and buffaloes followed by farmers have revealed that most of the feeding practices across the different locations in India are imbalanced characterized by under or overfeeding of energy and protein (Mudgal et al., 2003, Singh et al., 2002). Shortage of feeds and fodder apart from imbalanced feeding is one of the major constraints for improving the dairy production (Garg, 2012). Cost of feeding is the single most important factor affecting the profitability of a dairy enterprise as feeding cost accounts for more than 70% of total cost of milk production (Garg, 2012).

Considering the economic importance of feeding and the complexities involved in the precise formulation of diets for the critical nutrients for various categories of livestock least cost formulation packages using linear programming (O'Coner et al., 1989; Munford, 1996; Duangdaw et al., 2009; Chakeredza et al., 2008) and fuzzy logic (SalooKolayi et al., 2011) has been in vogue abroad since very long. However, the same has not been adopted by the dairy sector in India as dairy sector is unorganized and still evolving from subsistence to commercial scale. Dairy sector in India is characterized by large number of low producing animals, variations in the genetic potential, feed resources, body sizes, livestock holdings and farmers resources/capacity to adopt improved practices. Added to the variation in the feed resources, variation in the body weights and production potential of animals across the different regions makes the ration balancing

much more complex to the small and marginal livestock farmers who produce the bulk of milk in the country. A number of ration balancing tools like WinFeed (http://www.winfeed.com) and FeedSoft (www.feedsoft.com) etc. have been developed overseas that are either paid or free (trial versions) capable of formulating feeds for a wide range of species and range of nutrients targeted at professionals who have good knowledge of nutrition and soft skills. These software's have not been adopted widely by the small scale farmers in rural areas or the commercial farms in peri-urban India due to lack of awareness, knowledge and soft skills. Majority of the dairy farmers continue to manage the feeding following traditional way and very few of them use the services of professional. Even the software programs developed in India like - Make feed Dairy (www.clfmaofInida.org) and ration balancing program by NDDB exclusively for dairy sector has not been widely adopted by small scale farmers although they have been customized to suit Indian production systems and are reported to reduce the feed costs by 19-23% (Goswami, 2013) and increase in net income by 15-25% per animal in 11500 animals tested across seven locations (Garg, 2012). Some of the major limitations of these tools are that these were designed mainly for feed formulation by skilled and semiskilled people mainly from feed industry and practicing professionals with basic knowhow and skill sets to operate the tools and were never designed for small scale farmers with limited capacity and skill sets. Given the fact that the number of skilled people with the necessary expertise in least cost formulations are very limited relative to the number of end users and the fact that many of the farmers are not aware, lack access to professionals/tools and cannot afford to pay for the services resulting in poor adoption of least cost formulation tool. Further the animal husbandry departments and extension staff who have greater access to the large number of farmers give greater emphasis on health issues allocating larger resources and manpower to health coverage neglecting feeding aspects. Ration balancing program by NDDB addresses this limitation to a limited extent by identifying a livestock resource person dedicated for this program where in the services on ration balancing are provided on a continuous basis by the dairy co-operative societies (www.nddb.coop). However limited coverage in selected areas of dairy cooperatives and continued dependency on the skilled staff are some of the major limitations.

Expert system helps to overcome the problems related to the difficulties in working out the least cost formulations using a wide range of feed resources available with the farmers for the various categories of livestock leading to balanced feeding, cost reduction and profit maximization to a heterogeneous group of farmers and thus overcome the limitations inherent with the subject matter experts operating at the field. Expert system is a powerful tool that provides improved and sophisticated media for educating and transfer of technology to farmers and extension workers. It provides advisory services to the farmers according to their needs with available resources in a timely, easy, cost effective way without any dissemination loss. This leads to increased livestock and farm productivity, improved livelihood of farming community, reaching a larger section of farmers and encourages the farmers to improve his knowledge and awareness in farm management besides making him to become e-literate.

Considering the above facts, "Feed Assist" an expert systems has been developed to address these limitations. Feed assist - a farmer friendly ration formulation tool was specially developed in a multilingual mode ensuring that small scale farmers with limited knowledge and skill sets across different regions will be able to use this tool and interpret the results without any specialized training or assistance.

Materials and methods

The expert system computes balanced least cost rations for various categories of dairy animals as per the nutrient requirements of cattle and buffalo (ICAR, 2013b) using a choice of the feed resources available with the farmer. This system has been developed using MS-Access as back-end tool and Visual BASIC as front-end tool. The software is integrated with mobile apps for its wider use as mobile usage is much more common than the personal computers. The end user-farmer chooses the feed ingredients from the master list and provides the details of the animal with respect to the parameters like, body weight, average daily growth rate and milk yield. The expert system processes the data and provides a balanced diet at least cost utilizing the available feed resources in terms of the actual quantities of different feed resources that needs to be fed. The output is provided in a tabular and graphical display, showing the proportion

in terms of quantity and cost of the formulated diet for easy comprehension.

The expert system has three major components- databases, programming and the output solution.

1. Databases and data processing

The expert system has two sets of databases – nutrient composition of feeds and fodders, and the nutrient requirements of different categories of livestock.

Nutrient composition of feed stuffs in database cover a wide range of feed resources available in different regions of India and the composition of feed stuffs have been sourced from a wide range of published literature (ICAR, 2013a). Parameters for the composition include the dry matter, proximate principles and cost of the ingredient. Costs of ingredients have been included based on the prevailing rates for the traded commodities and for other resources that are not traded, costs have been provided based on the estimated values. Provision has also been made to include the concentrate mixtures as commercial dairy farmers and livestock owners under the cooperative sector invariably use concentrate mixtures in dairy rations. As the costs are dynamic changing with seasons, quality and locations the user can always use the actual value in the database to arrive at the realistic costs of the formulated diets,

Nutrient requirement of different categories of cattle and buffaloes have been sourced from nutrient requirements recommended by ICAR (2013b) while the range of body weights, average daily gains and milk production has been sourced from published literature from Indian studies and the basic animal husbandry statistics, (BAHS, 2013).

The data sets were subjected to data processing that included standardizing of the collected data, compiling to non-redundant data set and fitting of standard formula to calculate feed requirements and ration formulations as per end-user specified parameters in terms of the feed resource and animal category. A database has been developed with various tables in MS-Access and integrated those based on RDBMS concept (Figure 1). The data has been uploaded into the database.

2. Programming

A VISUAL BASIC program has been written to compute balanced least cost ration for dairy animals based on the nutrient requirements of selected category of the animal considering the list of feed resources defined by the end user. A multi-lingual user and farmer friendly graphical user interface (GUI) module (Figure 2) has been developed for providing the details of the animal with respect to the categories and parameters like body weight, average daily growth rate and milk yield by user, and the option to select feed ingredients available with the user from the master list. Based on selection of feed resources, animal category and other parameters like growth rate, maintenance and milk production, the system provides information on nutrient requirement in terms of DM, CP and TDN for maintenance, growth, reproduction and production. The program has facility to add, delete and modify feed master database with new resources or change the price and composition of the existing ones to account for the changes in the season, demand supply, composition due to processing or introduction of newer feed stuffs. Provision has been made for end-user to change ratio of feed components in terms of concentrate:roughage and the proportion of dry to green fodder based on availability and price due to seasonal variations. User can also set the constraints for fitting maximum and minimum level of inclusion of a particular feed resource or/and category of animal.

The least cost optimization program is developed based on Linear Programming Problem (LPP) for optimizing feed diet/ration at least cost. This is a mathematical algorithm to find the least-cost feeds that satisfy the nutritional requirements. Linear programming (LP) is a mathematical method for determining a way to achieve maximum profit or lowest cost based on list of requirements represented as linear relationships. The mathematical model developed by Leonid Kantorovich and George Dantzig during World War II to plan expenditures and returns in order to reduce costs to the army and increase losses to the enemy.

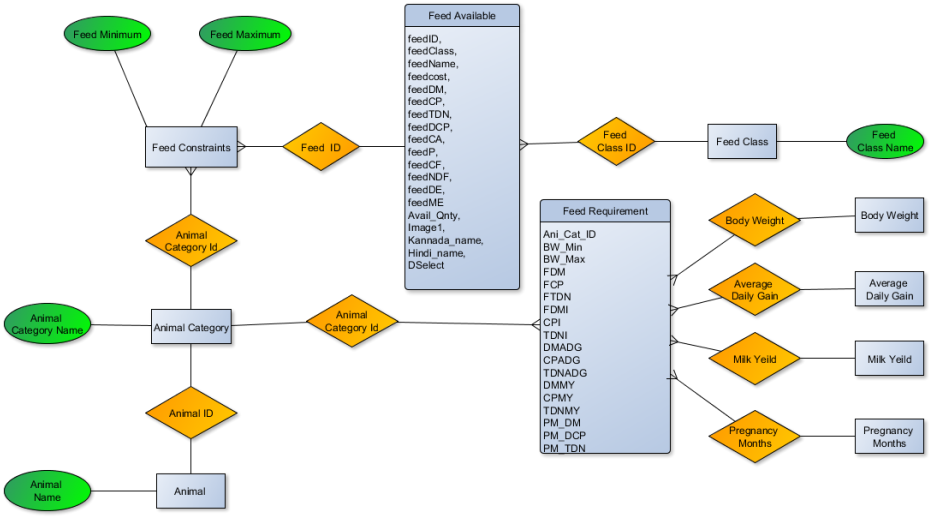
The standard form of linear programming is as follows.

Object function

$$\text{Minimise} \sum_{j=1}^{n} c_j x_j \rightarrow (j = 1, 2, 3, \ldots n)$$

Subject to constrains

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \qquad \sum_{j=1}^{n} a_{ij} x_j \geq b_i$$



Source: own processing

Figure 1: Entity Relationship Diagram of Feed Assist.

Let c_j is cost per unit of j^{th} feed, x_j is quantity of j^{th} feed , a_{ij} is quantity of i^{th} nutrient per quantity of j^{th} feed, b_i is requirement (maximum/minimum) of i^{th} nutrient from the diet.

Based on this concept, many researcher have demonstrated application of the LP in least cost ration formulation for dairy animal and poultry. Tozer (2000) has illustrated LP as Least-cost ration formulation for Holstein dairy heifers, Bassam (2009) for Broiler and Olorunfemi (2007) for Poults. Chakeredza (2008) and team has explained ration formulation using MS Excel. Here, we have described implementation of the least cost ration formulation tool for personal computer and mobile apps.

3. Solution output

After providing inputs of the animal details and defining the feed ingredients, user proceeds to formulate balanced ration by clicking on formulation icon that gives the desired output with details of selected ingredients with their quantities, cost and dry matter proportion of each ingredient and finally the total cost and its breakup of the diet (Figure 2).

4. Steps for formulation

a) Selection of animal category - species (cattle, buffalo) and category (heifer, dry, pregnant, milch etc.,) and production parameters like body weight (or body measurements – length and girth), growth rate, milk yield etc.,

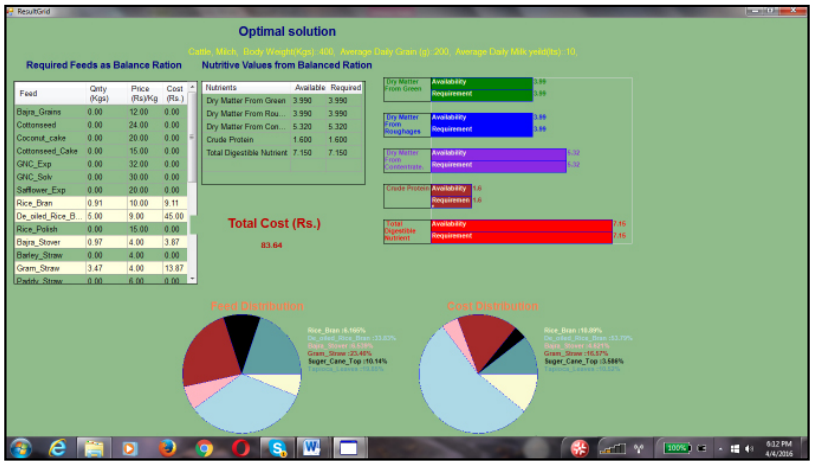
b) Selection of feed recourses available from the master list from the categories of concentrates, green roughages and dry roughages. Feed resources are categorized under three major categories – crop residues, greens and concentrates and the farmers have to select the feed resources available with him under each category.

c) Click on Formulation to obtain the least cost formulated ration. If the solution is not feasible with the specified parameters the system would prompt the same and the user is advised to modify the selection in feed resources selection by trial and error till he gets a feasible solution.

Farmer can obtain solution by clicking FORMULATION icon and the solution will display as Final Result form. The Final Result form (Figure 3) depicts the information on the category of the animals selected with the production parameters, list of user selected feeds, program selected feed resources their quantities and cost, total cost of diet, nutrient requirements as per the details of selected animal and nutrient available from the formulated balanced diet in terms of dry matter from green, dry roughage and concentrate, crude protein and total digestible nutrients. The output is presented in tabular and graphical form for quick comprehension and easy analysis of nutrients available against requirements. Graphical depiction about the proportion of cost and feed quantity in diet is provided by pie diagram to allow the end user to understand the cost breakup of the total diet. The program has provision to store the output solution and retrieving for feature use.

Source: own processing

Figure 2: Main Form of Feed Assist.



Source: own processing

Figure 3: Main Form of Feed Assist.

Source: own processing

Figure 4: Screen shots of mobile apps.

Results and discussion

In this section, a brief discussion has been made on the features of the software and how it differs from other least cost formulation packages/expert system already available in the market. Most of the least cost formulations require expertise to operate and farmers have to always depend on the professional help in accessing this services. Majority of these are developed for commercial use by feed industries to formulate compound feeds. Looking into the reasons for low adoption of the least cost formulations in dairy sector in spite of the fact that a number of studies using balanced diets have shown to improve the productivity and profitability of small scale dairy farmers (Garg, 2012), feed assist has been specifically designed to bridge this gap and allow the small scale farmers to take advantage of the powerful tool. Unlike other tools this expert system has been designed primarily for farmers use by simplifying the features- minimizing the steps involved and simplification of the features considering the major nutrients aided by the touch screen graphical user interface features using icons, pictures and graphs to ensure that any farmer with little practical knowledge on feeding with minimum literacy level will be able to operate this system independently. A balance has been struck between the ease of use and the features of the system restricting the important elements of feeding considering only cost, dry matter, protein and energy without considering fiber, minerals, protein quality, fats etc.

The expert system provides a powerful tool to the farmers in resolving the complexities involved in ration formulations as per the parameters defined by the farmers to suit his requirements without any help from the professionals. Thus this expert system empowers the farmers to operate themselves and understand the practical advantages of the benefits of least cost formulations without any assistance from external agents. This also provides an opportunity for the farmers to understand and appreciate the nitty gritty of ration formulation and try and test different combinations to suit his conditions without relying on the service providers who are difficult to access. The system can be installed on a personal computer, touch screen kiosk or as mobile application and ensure wider coverage of farmers across the different regions. As per the recent estimates, the number of mobile users in India is around 930 million covering 75% of the total population and fastest growth is being seen in rural subscribers (http://www.trai.gov.in/WriteReadData/WhatsNew/Documents/PR-TSD-Sep-14.pdf).

The operations are simple and initially a small demonstration to a group of farmers is required and the trained farmers in turn can assist the other farmers in access and using the system. Periodical follow up by the extension staff in the initial stages is required till the farmers get familiarized with the tool and once they understand, they can continue to use the system on their own and modify their diets with changes in the feed resources and individually optimize the diet to different categories of the animals with the available resources. The main features of the expert system which has been made user friendly are;

- **Data maintenance** – Has provision for addition of new feed resources, deletion and modification of feed master table with nutrient compositions and price of feeds. The changes are very easy to incorporate- by simply double clicking feeds list box, Feed Master Form would open and user can incorporate the desired changes in the feeds master table. Thus the features of software ensures that the data used in the least cost formulations are based on actuals and is dynamic to capture the changes relevant to the farmers situations.
- **User friendly** – The program is very easy to use with no need of special training and assistance to operate the system. Any individual with minimum skills and literacy capable of operating the mobile or bank Automated Teller Machines (ATM) can handle this expert system. Touch screen user interface feature similar to the ATM operation makes it easier to operate in providing the inputs and -- formulating least cost rations for various categories of animals in three simple steps- specifying the animal parameters, identifying the available feed resources and interpreting the solution provided.
- **Multi-lingual** - Has provision to be used with many languages, presently it is in three languages (Kannada, Hindi and English) and can be extended to other languages, input and output part is common and can be translated in other languages to cater different states/regions.
- **Storing and retrieval** – user can save the solution and retrieve the saved solutions
- **Display and printing** - Provides results in tabular, graphical form - bar chart and pie charts, which gives an instant overview of the solution and the formulated diet with its components. Has facility for printing and downloading.

- **Dual versions** - Basic and advanced. Basic version is designed for farmers where the body weight calculation can be carried out based on the heart girth and length of the animal and few of the components are set to default values and some edit features are locked given the fact that farmers do not have the required skills to alter/edit and make the solution practical and feasible. Advanced version is for professionals where the scope of changing/editing most of the data like nutrient requirements, changes in upper and lower limit for specific resources, changes in proportion of roughage to concentrate etc., is possible
- **System requirements**

  Computer configurations requirement: Hardware; Pentium Dual Core and above with 1GB RAM, OS; windows XP and above with .net 2.3 and above.
- **Mobile apps on Android 5.1.1 version** (Figure 4).

The expert system "Feed Assist" can play an effective role in scientific feeding and in improving livestock production of small/ marginal and landless livestock farmers as this is user friendly and can be used by the farmers themselves with minimum demonstration without any help from the expert. Feed assist expert system utilizes the available information on nutritive value of feeds and fodders and the nutrient requirement for various categories of livestock based on the Indian studies and match these two data sets to provide optimum solution to formulate the diets considering the nutrients, cost and the parameters specified by the farmer customized to his situations. Under field conditions formulating a balanced diet with the available resources is one of the major challenges as the farmer, field extension staff or vet is most of the times unaware or has limited knowledge of requirement for different categories and nutrient content of common feeds. The feed assist can be useful tool in taking care of this limitation wherein a variety of diets can be balanced at minimum costs using a combination of feed resources that are locally and readily available with the farmer for all categories of livestock. This can also help in decision making in terms of the feed ingredients to be purchased from a range of ingredients available locally and priced differently.

Presently feeding system in India for dairy is mostly traditional or conventional relying mainly on the crop residues and by products as dairy is very closely integrated into crop livestock system. With commercialization and emerging of dairying as an economic enterprise with greater reliance on purchased feed inputs, feeding for optimum returns is catching up and gaining significance. The expert system feed assist can play an important role in regulating feed costs and/or improving feed utilization through empowering the small holder farmers and improve their livelihoods and incomes through profitable dairying. This tool can help in achieving improving efficiency through balanced diets avoiding underfeeding or overfeeding either of which leads to loss of productivity and profits. The tool will also help the farmer in making the right decision regarding the type and quantity of feed ingredients to be purchased based on the least cost solution and maximize the use of his farm produced by products leading to economic balanced diets. Additionally this tool could also be useful for feed industries, researchers and extension staff in feed formulations for economic feasibility studies, extension and advisory services.

As an illustration least cost formulations using the feed assist expert system for various categories of animals is presented in Table 1. Different feed resources representative of different regions in India has been used in the illustration. The table contains information regarding nutrients requirement of different categories, description of animal parameters,, range of feed resources available with the farmers and the optimal solution of suggested feeds with nutritive values and total cost of the balanced feed.

The software has been already demonstrated at various fora involving the farmers, state extension agencies and dairy cooperative staff and the feedback received from this forums indicate that most of the times the prevailing feeding practices in dairy animals are imbalanced. The solution offered by the expert system when adopted can lead to balanced feeding with cost reduction. Currently the software is being pilot tested at village level dairy cooperative society of Karnataka Milk Federation center in association with the NGOs and the findings of the testing would guide us to further refine the existing features of the expert system to make it more robust and upscale it to cover larger number of dairy farmers.

Animal details	Nutrient required DM, CP, TDN (kg)	Feeds selected and price per Kgs	Suggested Feed, Quantity with price and total cost				Nutrients from feeds-DM, CP, TDN
Animal - Cattle, **Category** - Heifer, **Body weight** - 200, **ADG** - 250, **Milk yield** - 0, **Pregnant months** - 0	DM -5.25, CP -0.51, TDN -2.62	Cottonseed_Cake:15.00, De_oiled_ Rice_Bran:9.00,Maize_Grains:14.00, Rice_Bran:10,Hybrid_Napier:2.00, Bajra_Fodder:2.00,Maize-Fodder:2.00, Paddy_Straw:6.00, Gram_Straw:4.00		**Quantity**	**Price**	**Cost**	DM-5.25 CP-0.51, TDN-2.90
			De_oiled_Rice_Bran	2.38	9.00	21.43	
			Gram Straw	2.33	4.00	9.33	
			Napier	4.20	2.00	8.40	
			Total cost			39.16	
Animal - Cattle, **Category** - Dry, **Body weight** - 400, **ADG** - 200, **Milk yield** - 0, **Pregnant months** - 0	DM -8.20, CP -0.64, TDN -3.85	Cottonseed_Cake:15.00, De_oiled_Rice_ Bran:9.00, Hybrid_Napier:2.00, Sugarcane tops:2.00, Paddy_Straw:6.00, Gram_Straw:4.00		**Quantity**	**Price**	**Cost**	DM-8.20, CP-0.72, TDN-4.28
			De_oiled_Rice_Bran	3.64	9.00	32.80	
			Gram Straw	3.64	4.00	14.58	
			Sugarcane tops	1.82	2.00	3.64	
			Total cost			51.02	
Animal - Cattle, **Category** - Milch, **Body weight** - 450, **ADG** - 200, **Milk yield** - 5, **Pregnant months** - 0	DM -11.75, CP -1.17, TDN -5.81	Jowar_Grains:15.00, Cottonseed_ Cake:15.00, Mustard_Cake_Solv:14.00, Gram_Husk:10.00, Wheat_Bran:15.00, Wheat_Straw:4.00, Lucern:3.00, Hybrid_ Napier:2.00		**Quantity**	**Price**	**Cost**	DM-11.75, CP-1.18, TDN-6.49
			Mustard_Cake_Solv	1.79	14.00	25.11	
			Gram_Husk	3.39	10.00	33.89	
			Wheat_Straw	5.22	4.00	20.89	
			Hybrid_Napier	9.40	2.00	18.80	
			Total cost			98.70	
Animal - Cattle, **Category** - Milch, **Body weight** -500, **ADG** - 0, **Milk yield - 10, Pregnant months** - 0	DM -15.10, CP -1.55 TDN -7.23	Wheat_Straw:4.00, Cottonseed_Cake:15.00 Mustard_Cake_Solv:14.00, Wheat_ Bran:15.00, De_oiled_Rice_Bran:9.00, Jowar_Grains:15.00, Lucern:3.00, Hybrid_ Napier:2.00		**Quantity**	**Price**	**Cost**	DM-15.10 CP-1.72, TDN-8.39
			Mustard_Cake_Solv	1.67	14.00	23.43	
			De_oiled_Rice_Bran	5.00	9.00	45.00	
			Wheat_Straw	6.71	4.00	26.84	
			Hybrid_Napier	12.08	2.00	24.24	
			Total cost			119.44	
Animal - Cattle, **Category** - Pregnant, Milch, **Body weight** - 500, **ADG** - 0, **Milk yield** - 10, **Pregnant months** - 7-8	DM -16.09, CP -2.29 TDN -7.45	Jowar_Grains:15.00, , GNC_Solv:30.00, Sunfflower_Exp:20.00, , Gram_Husk:10.00, De_oiled_Rice_Bran:9.00, , Wheat_ Bran:15.00, Jowar_Stover:4.00, Gram_ Straw:4.00, Ragi_Straw:5.00,, Lucern:3.00,, Para_Grass:2.00, Soybean_Meal_Solv:30.00		**Quantity**	**Price**	**Cost**	DM-16.10, CP-2.29, TDN-9.42
			Soybean_Meal_Solv	2.08	30.00	62.42	
			Rice_Bran	0.07	10.00	0.71	
			De_oiled_Rice_Bran	5.00	9.00	45.00	
			Ragi_Straw	5.36	5.00	26.82	
			Para_Grass	19.31	2.00	38.62	
			Total cost			173.33	

Note: All feed quantities in kg on as such basis, price in INR
Source: own processing

Table 1: Illustration of the feed assist formulated balanced diets for various categories of animals with different resources.

Conclusion

This expert system is specifically designed for use by small scale farmers with limited skill sets and involves simple operations that are greatly facilitated by touch screen interface features. The input variables with regard to the animal parameters and feed resources are chosen by farmer to suit his production situations. A fine balance has been achieved between the simplicity of the system and the essential features of the balanced diet to ensure its wider adoption. It facilitates the farmers in enhancing their knowledge on feeding of different categories of dairy animals in a profitable manner using the available local resources without relying on the skilled professionals. The format of the output from the system is easy to understand and ensures that farmers make use of their feed resources to the maximum extent and the animals are fed optimally to support milk production in a profitable way increasing the overall livestock productivity, income and livelihood of the farmers. Current feeding practices followed in dairy are mostly traditional and there is ample scope to improve productivity and profitability through proper ration balancing and the Feed Assist - expert system would be a powerful decision making tool on feeding practices for every dairy farmer specially the small holders who have limited access to information on improved feeding practices or the services of extension staff. Optimization module of the expert system can be used for formulating concentrate mixtures or total mixed rations with minimum cost and maximum utilization of nutrients based on an objective function and a set of constraints/restrictions. The tool can be used on mobile as an Android application and given the wider usage of mobiles in rural India the chances of adoption and the benefits

from the adoption of this tool are likely to be high among the rural small holder producers who constitute the major share of the dairy sector in India.

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