

FORMULATING THE LEAST COST FEEDING STRATEGY OF A CUSTOM FEEDING PROGRAMME: A LINEAR PROGRAMMING APPROACH

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Abstract: The profitability of a developmental project depends on effective use of available resources. That is normally referred to as appropriate decision making that requires a computation of a feasible option among several options to determine the optimal choice. To do that (get the optimal choice) a mathematical technique called Linear Programming was used in this study to provide the cost minimisation option (feed ration). The feed ration that was computed is the least cost feeding strategy (cheapest feed ration that meets the dietary requirements of cattle) appropriate for the custom feeding programme run by the National Agricultural Marketing Council (NAMC). The custom feeding programme, like commercial feedlots, keep animals in a zero grazing and unlike the commercial feedlots accepts even older animals. Noteworthy is that the cost of feed constitute the biggest input used in the custom feeding programme (more than 60% share of total cost of all input used). Therefore, minimising the cost of buying feed is very important to the NAMC and all stakeholders involved in purchasing of feed. The optimal solution indicates that the least or cheapest feed would cost the NAMC R4.71c/kg which is a combination of VM and MB. The most expensive feed to add in the ration would be Lucerne and yellow maize meal. The feasible solution has surpluses of each of the required nutrients.

Keywords: Beef, NRMDP, Linear Programming, Feed, Optimization

Introduction

The profitability or sustainability of a business or developmental project depends on the effective use of available resources (Mehdipoor, Sadr-ol-ashraafi, & Karbaasi, 2006). Commercial sector focuses its attention in either reducing costs or maximising profits (commercial feedlots). The marketing challenges and other challenges facing smallholder farmers (high transaction costs) continue to keep these farmers at the periphery of mainstream business. In South Africa feedlots play an important role in the formal livestock industry and in 2004 had the handling capacity between 400 000 to 420 000 cattle. The turnover stood at 3.6 times meaning that roughly 1.4 million cattle work their way through the feedlots into the formal slaughter. Considering 1.9 million total slaughters during the same period, this represents about 75 percent. It is essential that the South African feedlots achieve maximum efficiency in transforming grain into meat. South Africa seeks to transform a weaner into a slaughterable animal with an efficiency ratio of 12 kg of grain to one kg of meat. This study was instituted to come up with a least cost feeding ration (R4.71 consisting of two feeds) of the custom feeding programme from available feed rations.

Marketing challenges facing smallholder farmers in South Africa

Jordaan & Grove 2014; Emongor, Louw, Kirsten & Madevu, 2004; Gong, Parton, Zhou & Cox, 2004 argue that the performance (in terms of market access) of smallholder farmers remains poor in spite of all government efforts. The argument for the failure of smallholder farmers can be attributed to, among other aspects, the behavioural aspects of these farmers towards government incentives. This argument by Jordaan et al (2014) is a development from the argument that transaction costs are the biggest barrier faced by smallholder farmers in accessing the formal markets in

South Africa. However, Musemwa et al (2007) argue that remote location of most emerging cattle farmers coupled with poor road networks, result in high transactional costs reducing the price that traders are prepared to pay for the cattle. Makhura (2001) and Nkhori (2004) note that even if emerging farmers are in areas with good road linkages, the distance from the formal markets tends to influence transaction costs.

It is clear that formal and informal institutional aspects and their role in marketing and economic development revolve around transaction costs, market information flows and the institutional environment. Various researchers affirm that emerging farmers in rural economies; lack adequate market information and contractual arrangements; lack lobbies in the legal environment; and are not easily receptive to changes (Delgado, 1999; Kherallah, 2001). These factors result in high transaction costs, hence emerging farmers' face difficulties in accessing and participating in formal markets remains. The use of spot markets may not be as rewarding to the farmers as formal markets are, mainly due to traders' opportunistic behaviour. In addition, spot markets are becoming less popular in the liberalized environment (Kachingwe, 2009; Jagwe, Ouma & Machete, 2007).

In many instance a blanket approach is used in addressing the fundamental question of whether or not the formal market remains the best way in all situation. The rationality arguments that selling decisions mostly depends on the returns farmers accrue from selling a product to a certain market seems to be neglected in many instances (and the approach is that formal markets are the ultimate goal). The experiences by Ntombela et al (2013) of the custom feeding programme may present a challenge to the conventional view. For instance, communal farmers receive higher prices for their old animals in the informal markets as opposed to what they would get from the formal market. There is an undeniable fact that changes in seasons means changes in the conditions of livestock owned by smallholder farmers with winter being the challenging of seasons. The weather conditions accompanying the first rains also determine the extent of losses smallholder farmers find themselves in during a particular year. The custom feeding programme has proven to be a great buffer against the challenging seasons of the year to farmers who have access to the facilities. The commercial feed lot serve a different purpose of conditioning and selling younger animals.

Formal feedlots as a market channel

Feedlots play an important role livestock industry and in 2004, South Africa had a handling capacity between 400 000 to 420 000 cattle (Grant et al., 2004). The turnover was 3.6 times meaning that roughly 1.4 million beef cattle moved through the feedlots into the formal slaughter. Normally, purchasing a weaner at 220 kg (live weight), the feedlots seek to double the mass of such an animal in 100 -110 days to bring it up to a 220 kg carcass. The South African Feedlot Association (SAFA) argues that the average American cow takes 24 kg of feed to add 1 kg of meat. This means two years and three months to get it to the slaughter house. Meanwhile, the average South African cow makes it in 12-14 months (Grant et al., 2004). Most slaughtering in South Africa is done through abattoirs. It is important to outline that there are about six categories of abattoirs in South Africa ranging from A to F. Level A abattoirs can slaughter up to 1000 animals a day, they have a state vet and the meat is graded on sight. Level B abattoirs have a capacity of slaughtering up to 500 animals a day. While Level C abattoirs have the capacity to slaughter up to 8 animals a day.

The class A and B abattoirs account for 80 percent of all slaughtered cattle. The larger abattoirs are increasingly integrating forward and backward into the value chain such as feedlots and deboning/butchering (Grant et al., 2004). Some of the larger abattoirs still slaughter a portion of their production on contract for other companies, but most of them are now taking ownership of the animals to control their through-put. The economics of slaughtering, is quite tight and there is very little margin for error. Therefore, by integrating backwards to supply, the abattoirs can control the prices and negotiate best prices with the weaner producers to get direct delivery to their feedlots. The forward integration requires greater quality control as they are now producing finished product that they are transporting in boxes and primal cuts instead of carcasses. However, it also requires more efficient marketing approach such as arranging contracts with buyers. This means more rigorous quality control standards such as Hazard Analysis and Critical Control Points (HACCP) and Global Gap programmes and/or retail oriented codes for example Woolworths.

Custom feeding programme

In rural areas across the country poor or remote areas livestock farming forms the backbone of agriculture. Livestock is an important if not their biggest productive asset for many households. This is against the background that about 40% (and more for goats) of all cattle in South Africa are owned by communal and/or emerging

(‘developing’) farmers Van Zyl, McCrindle and Grace, undated. Nationally, only about 5% of cattle owned by developing farmers find their way to the market every year (under clear traceability rules), compared to nearly 20% of the animals owned by commercial farmers. Commercial farmers market two to three times more animals than developing farmers and realize gross margins per head that are three to four times greater than smallholder farmers. The complexities and the non availability of readily distinct information as well as high transaction costs within the developing sector make it a challenge for any formative intervention. Livestock production and more specifically livestock marketing represent a major untapped source of income for many of the country’s poor households that own these animals. If smallholder farmers could increase their annual off-take rate from 5% to only 8%, it would reduce the need for 10 000 to 35 000 tonnes specific meat cuts that are imported every year.

However, the challenges of doing so on a sustained basis are formidable and widely recognized: a limited resource base, production systems that are not geared to respond to the market and inadequate access to the market. Many attempts have been made to overcome these challenges, mostly focusing on production issues such as genetic improvement, husbandry practices and disease control. In many instances, significant progress has been made, but has failed to raise the off-take rate noticeably. The research conducted by ComMark Trust (?) indicated that, relative to commercial farmers, emerging and/or communal farmers in the Eastern Cape Province were earning far less income from their livestock assets. The Umzimvubu Red Meat Project (URMP) commenced in beginning of 2008, with the primary objective of using the experience gained from the ECRMP to assist farmers in the Alfred Nzo District Municipality (ANDM) to take full advantage of these opportunities. Where it appears that a particular market is not generating the benefits for poor households that could be expected, the structure and functioning of the market are researched to understand why this occurs and pilot interventions are designed and implemented accordingly.

In terms of the market for red meat in South Africa, the research revealed that higher marketing costs per head of cattle, distrust of formal markets, poor herd structure and high rates of stock theft reduce the quantity of animals owned by emerging/communal farmers that reach formal markets, i.e. registered abattoirs and auctions. When emerging/communal farmers do sell through formal markets, the poor condition of the cattle, i.e. poor health and/or poor age characteristics, generally result in low grading and low prices per kilogram. The common perception from the bulk of the buyers is that the developing sector invest nothing or very little on their livestock. As a result of these factors the income generation of small scale farmers is very low. During dry spells (winter and drought) the marketing rate is totally eclipsed by mortalities and thus the developing farmers derive very little from an enterprise that has the capacity to feed the country. The net result of this under-development is that SA continues to import meat and thus the communal livestock is trapped into the “dead asset” doldrums.

The programme was inherited by the NAMC when the support from Commark came to an end. Interestingly, ever since the programme has seen major expansion within the Eastern Cape and recently moved to KwaZulu Natal, Limpopo, and Northern Cape and received major funding boost from the Department of Rural Development and Land Reform. In partnership with a number of municipalities and municipal agencies together with Provincial Departments the future of the programme has started to shape up well. Sustainability of the programme is one of the major challenges and its cost effectiveness has been closely monitored and engagements of important stakeholders bear the necessary results (feed manufacturers agreeing on direct purchasing of feed). *Since feed purchases constitute the biggest input share by value (and even volume) a close look at the ways on finding the least cost ration is important. The use of a mathematical technique to compute this was done (see the methodology description in the sections to follow). Before getting to describe the methodology an outline of the factors that influence the cattle’s nutrient requirement are briefly explained.*

Factors that affect cattle nutrition

The nutrient requirements of each of the different cattle breeds are determined by a number of factors. In this regard, the Angus Education Center (undated) argues that cattle nutrition is influenced by both: biological and ecological factors. This means, a clear understanding of these factors can help in outlining the nutritional requirements. It needs to be noted that, in this study it is very difficult to be sure of the nutrient requirements of the cattle in the custom feeding programme as their genetic make up is not well defined. The lack of a proper definition and record keeping of the genetic makeup of the communal herd rest with the free movement of bulls of different breeds mating with cows that came from the same environment. The resistance the animals have to a number of natural eventualities have led to the general treatment or classification of them as Nguni animals knowing for a fact that

cross breeding within the animals blood line may have occurred. Nonetheless, factors affecting cattle nutrient requirement include, among others, breed type, genetics, animal size, animal age, cattle condition, digestive system functions.

Methodology used - Linear programming

The development and evolution of linear programming can be traced back to the World War II, even though during that time it was kept as a secret. After the war (around 1947) industries started to use it. Linear programming is traced back to George Dantzig who published its simplex method, followed by the development of the theory of duality by John von Neumann, and lastly Leonid Kantorovich applied similar techniques won the Noble Prize in 1957. In 1984 Narendra Karmarkar introduced a new interior-point method for solving linear-programming problems. From there linear programming has continuously been applied by the researchers and policy advisors improve operation or decision making. With the development and evolution having been briefly outlined, an explanation of the concept becomes paramount. Linear programming can be defined as a mathematical technique for determining the best allocation of a firm's limited resources to achieve optimum goal. The term (linear programming) covers a whole range of mathematical techniques aimed at optimizing performance in terms of combinations of resources (Lucey, 1996).

An optimum solution is a solution that fulfils both the constraints of the problem and the set objective to be met. The term "linear", as stated by Akingbade (1996), implies proportionality, which means that the elements in a situation are so connected that they appear as straight line when graphed. While the "programming" indicates the solution method which can be carried out by an iterative process in which a researcher advances from one solution to better solution until a final solution is reached which cannot be improved upon. This final solution is termed the optimal solution of the LP problem. Linear Programming can be described as is a mathematical technique that aims for optimization (maximise or minimise) of a linear function, within a given (subject) set of linear constraints (Martine, 1983).

The linear model consists of the following components: A set of **decision variables** - this is what is not known when the problem is started normally represent what can be controlled or adjusted. The aim is to get the best value for the problem at hand. In general, there are quantities you can control to improve your objective which should completely describe the set of decisions to be made. An **objective function** - is a mathematical expression or linear function of variables which is to be optimized that combines the variables to express the desired goal. This is where it is specified whether the aim is to minimise cost or minimize profit. A set of **constraints** - are a mathematical expressions that combine variables to express the limits of the possible solution. **Variable bound** - only rarely are the variables in an optimization problem allowed to take any form from minus infinite to positive infinite (this is not applicable in this case). Therefore, Fagoyinbo & Ajibode (2010) argues that a linear programming problem may be stated in the following for:

The objective Function (cost minimisation)

$$Z = C_1X_1 + C_2X_2 + C_3X_3 + \dots + C_nX_n \text{ (objective function)} \dots \dots \dots (1)$$

- Z – Least Cost Ration (Ration Cost)

- X – Feed Type

- C – Feed Price/Cost

In this study the equation can be expressed in real terms as (this includes all the feeds that were included and their market prices):

$$MIN = 6.0 * VM + 5.40 * VSB + 5.30 * VS80 + 5.90 * MFC + 4.70 * MB + 5.40 * FSB300 + 5.30 * FSB460 + 2.2 * Lucerne + 5.3 * Ymaize;$$

Subject to the linear constraints as follows

$$A_{11}X_1 + A_{12}X_2 + A_{13}X_3 + \dots + A_{1n}X_n (\leq \text{ or } \geq) b_1 \dots \dots \dots (2)$$

$$A_{121}X_1 + A_{22}X_2 + A_{23}X_3 + \dots + A_{2n}X_n ((\leq \text{ or } \geq) b_2 \dots \dots \dots (3)$$

$$X_1, X_2, X_3, \dots, X_n ((\leq \text{ or } \geq) 0 \dots \dots \dots (4)$$

- A – Nutrients (such as Crude Protein)
- B (1 or 2) – Minimum amount of each nutrient required for optimal growth or fattening

Example of Crude Protein is as follows:

$$\text{Crude Protein} = 100 * VM + 300 * VSB + 800 * VS80 + 450 * MFC + 330 * MB + 300 * FaSB300 + 115 * FaSB460 + 20 * Lucerne + 8 * Ymaize \geq 1.9$$

From the above equations it can be seen that there are no-negative constraints: linear objective function has to be optimised (in the case of this article minimised), various linear constraints or available inputs, and non negative constraints.

The Importance of Linear Programming - Many real world problems lend themselves to linear programming modelling. These include but not limited to manufacturing, finance (investment), and agriculture. The output generated from linear programming packages provides useful “what if” analysis. **Advantages** - The linear programming technique helps to make the best possible use of available productive resources (such as time, labour, machines etc). **Disadvantages** - Linear programming is applicable only to problems where the constraints and objective function are linear i.e., where they can be expressed as equations which represent straight lines. In real life situations, when constraints or objective functions are not linear, this technique cannot be used. Factors such as uncertainty, weather conditions etc. are not taken into consideration. **Assumptions of the linear programming model** - The parameter values are known with *certainty*. The objective function and constraints exhibit *constant returns to scale*. There are *no interactions* between the decision variables (the additivity assumption). The *Continuity* assumption: Variables can take on any value within a given feasible range.

Materials and Methods

LINGO was used in programming the problem to come up with an optimal solution. The dataset used for this study was collected as from feeds that are sold by a number of feed companies, available nutrient analysis of some feeds/stock and the price information was collected from the retail environment. Information regarding the nutrient requirements of different groups in this was gathered from feed nutrient composition (available mostly in the feed label and accessed through the feed manufacturer’s websites). There are over seven (9) feeds from which an optimal solution had to be drawn from, namely, VM (R6.00/kg), VSB (R5.40/kg), VS80 (R5.30/kg), MFC (R5.90/kg), MB 33 (R4.70/kg), FSB 300 (R5.40/kg), FSB 460 (R5.30), Lurcene (R2.20/kg), and Yellow maize meal (R5.30). The price information was gathered from the outlets that sell these products mostly around the Eastern Cape.

- Nutrient composition was collected from feed labels (available in all used feed manufacturers)
- Feed price information was collected through invoices gathered from suppliers of these feeds (mostly around the Eastern Cape)
- Minimum nutrient requirements of cattle - University of Oklahoma and Lalman, undated
- Maximum tolerance levels - University of Oklahoma and Lalman, undated

Analysis of the results

All the necessary check of a linear programming solution was done. The optimal solution was found to be R4.71 while the total infeasibilities stood at zero (0) – this means no constraints or variable bound were violated and was also observed that LINGO took 1 iteration to solve the model. Then having looked at the feasibility of the LINGO output or result and decision to analyse three important variables was done. Therefore, the analysis focuses on three important areas: the objective function followed by the reduced costs and the slack/surplus.

Objective function analysis provides a clear indication the possible minimum cost/kg of feeding an animal in the programme with the required nutrients. Indicated in **Table 1**, the minimum amount possible to feed beef cattle stands at **R4.71**. The programme out of the nine (9) feeds chose a combination of VM feed and MB accounting for 0.11gram and 0.99 grams to constitute a kilogram. Since this is not practical, in purchasing terms, cattle consuming 10 kg/day would cost the NAMC about **R47.10**. This implies in the feed purchasing, of the 10kg required 9 kg should be MB while 1kg needs to be VM. In short, the cost effective feeding or feed purchases would constitute 10% of VM and 90% MB.

Table 1: Feeds that constitute the least cost feeding ration (in kg, 10kg and %)

Feeds used	KG makeup	kg/day per cattle	Percentage share
VM	0.11	1	10%
MB	0.99	9	90%
Totals	1.11	10	100%
Cost /kg and 10kg)	R4.71	R47.10	

Source: LINGO output and own calculation

Reduced cost analysis – provides an analysis about the cost implication of including in the ration any of the unused feeds. This can be put as the amount of penalty one would pay from introducing a unit of unused feed. **Table 2** clearly indicates the reduced associated with introducing unused feeds. The means for that introducing a VSB, VS80, FSB300 and FSB460 to the feasible ration would increase the total cost/kg by R0.70c, R0.60c, R0.70c and R0.60c respectively. This means introducing these meals/feeds individually would not increase the total cost/kg much. However introducing Lucerne and yellow maize meals/feeds individually would lead to R2.20c and R5.30c from the original increase in the feasible solution. This means introducing these two feed would increase the cost of feeding the animals in the program.

Table 2: List of feeds that are excluded from the feasible ration and the associated costs of inclusion

Unused Feeds	Reduced Costs
VM	0.00
VSB	0.70
VS80	0.60
MB	0.00
MFC	1.20
FSB300	0.70
FSB460	0.60
Lucerne	2.2
Yellow Maize	5.30

Source: LINGO output

Slack or surplus analysis – looks at how close (in terms of nutrients) is the solution from meeting/satisfying the constraints as equality. Since the constraints in this study was to get the minimum nutrients or greater than the minimum (\geq) then the values in Table 3 are surpluses. In Table 3 it can be seen that none of the constraint were violated (such as having the minimum requirement – RHS exceeding the sum nutrients in all available feeds - LHS). The surplus values indicate the amount of each nutrient in the feasible solution by which it exceed the minimum daily nutrient requirement. In Table 3 for example, for crude protein there surplus of 3.25.54g/kg, the same for all other nutrients presented in Table 3. What need to be looked at are the highest tolerance levels of each of these nutrients so as to ensure that the feed ration is indeed the correct feed.

Table 3: Nutrient Surpluses

Nutrients	Unit	Surplus/Slack	Dual Price	Required nutrient (RHS)	Maximum tolerable levels
Crude Protein	g/kg	325.54	0.00	1.90	
Urea	g/kg	88.98	0.00	1.90	
Crude Fibre	g/kg	116.78	0.00	3.00	
Moisture	g/kg	106.04	0.00	14.40	--
Fat	g/kg	0.12	0.00	0.01	
Calcium	g/kg	44.57	0.00	0.06	--

Nutrients	Unit	Surplus/Slack	Dual Price	Required nutrient (RHS)	Maximum tolerable levels
Manganese	ppm	279.33	0.00	20.00	1000
Copper	ppm	56.92	0.00	10.00	100
Cobalt	ppm	1.89	0.00	0.10	10
Iron	ppm	298.61	0.00	50.00	1000
Iodine	ppm	2.82	0.00	0.50	50
Zink	ppm	200	0.00	30.00	500
Vitamin A	IU/kg	4833.33	0.00	26000.00	None

Source: LINGO output; Lalman (undated)

Conclusions

Effective use of resources is one of the most important factors of a business or development project. There are available mathematical tools that can be used in the formulating the most feasible decision. South Africa's emerging/smallholder farmers have been on the periphery of mainstream market for a long time and many government interventions have not produced the desired outcomes. Feedlotting (in a customised way) has the potential of assisting in reducing animal losses in winter and assist in marketing the livestock of these farmers. This study was initiated to put together a feasible (cost wise) feed ration that has the required nutrient requirements. The objective function or the minimum possible amount/cost per kilogram of feed is R4.71 (this meant R47.10 a day to feed animals that consumes 10kg/day) which includes VM (10%) and MB (90%). This means using the market prices and the nutrient content of the available feeds those two are the cheapest while meeting all the nutrient requirements. The inclusion of Lucerne and yellow maize meal are the most costly of the unused feeds. In the feasible ration there are surpluses of each of the nutrients. This surplus need to be checked against the tolerance levels.

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