Review of Livestock Feed Formulation Techniques

Omidiora, Elijah Olusayo¹, Adegoke, Benjamin Olusesan²* & Aderounmu Ganiyu Adesola.³

¹Department of Computer Science and Engineering, Faculty of Engineering, LAUTECH, Nigeria;
²School of Engineering, Osun State Polytechnic, Iree, Nigeria;
³Department of Computer Science and Engineering, Faculty of Engineering,
Obafemi Awolowo University, Ile-Ife, Nigeria.

1. Introduction
Ration can be defined as the total amount of feed given to the animals on daily basis. Animal feed formulation can be defined as the process by which different feed ingredients are combined in a proportion necessary to provide the animal with proper amount of nutrients needed at a particular stage of production. As the world population increases, one of the major problems facing developing countries of the world is their ability to cope with protein requirement for the growing population. Poultry, which offer meat and egg on account of its short gestation, short generative interval and handy size is expected to play a major role in the bid to provide protein of animal source. It is reported that the most commonly kept livestock is poultry and that over 70% of those farmers kept chickens. Feed formulation is very important in raising animals because feed cost between 65% and 70% of the total cost of production in poultry production as identified by literatures.

Abstract
This paper reviews animal feed formulation methods, the conventional methods and intelligent system method. Highlighting their cons and pros. The intelligent system method (neuro-fuzzy) incorporated fuzzy conjunctive into levenberge training of artificial neural network. The neuro-fuzzy system was trained with dataset and validated using Amino acid elements of chicks feed. With 0.05 level of significance on NCCS 2000 platforms, output of the neuro-fuzzy system produced a correlation coefficient of 0.888608 and p-value of 0.97. Intelligent system can be employed to increase productivity in the field of animal feed formulation.

Keywords: animal feed formulation, linear programming, neuro-fuzzy, ration.

2. Livestock Feed Formulation Methods
There are about six conventional livestock feed formulation methods identified by Imamidoost, 1992 and Jerry, 2003. These methods include; Pearson Square method,

2.1 Pearson Square Method
This method is relatively simple and easy to follow. Some of its merits as identified by Afolayan and Afolayan include: its simplicity of use and secondly its usefulness for balancing protein requirement. Its disadvantages include, its usability for only two(2) requirements at the same time and secondly, its reduced consideration given to other nutritive requirements especially, vitamins and minerals.

2.1.2 Simultaneous Equation Method
This is an alternative method for the square method using a simple algebraic equation. Here, a particular nutrient requirement is satisfied using a combination of two feed ingredients.

Merits of Simultaneous Method
The system is easy to use both by beginners and the experienced feed millers. It is used to introduce feed formulation to students in teaching classes. Advantages of simultaneous equation over Pearson method are:

Firstly, farmer can balance for both protein and energy. Secondly, it is useful in considering more than two feed ingredients at once when balancing more complex ration. Finally, as the requirement increases, the system of equation increases.

Limitations of Pearson Square and Simultaneous Method
The limitations includes firstly, it satisfies only one nutrient requirement and uses only two feed ingredients. Another limitation is that the level of the nutrient being computed should be intermediate between the nutrient concentrations.
of the two feed ingredients being used.

2.1.3 Two-By-Two Matrix Method.
This method solves two nutrients requirement using two different feed ingredients. A 2 by 2 matrix is formed a set and a series of equations are solved to come up with the solution to the problem.

2.1.4 Trial and Error Method.
This is the most popular method of formulating ration for the swine and poultry. It is a type of feed formulation used in many developing nations of the world (Adejoro 2004), Nigeria inclusive. As the name implies, the formulation is manipulated until the nutrient requirements of the animal are met. This method makes possible the formulation of a ration that meets all the nutrient requirements of the animal. In poultry feed formulation, various cases of mineral deficiency such as osteomalacia, rickets and shelllessness or soft shell formation may not be properly addressed if care is not taken to comprehensively analyze or calculate the level of calcium and phosphorus of the ration in question.

2.1.5 Imami Method.
This is an educational way to describe and balance simple rations by a common calculator with a high accuracy for farmers who do not have access to the computer.

2.1.6 Linear Programming (LP) Method.
This is otherwise called, least cost computerized feed formulation. This method of determining the least cost combination of ingredients using a series of equations which employs Linear Programming methods. This least cost can employed in feed formulation takes basic seven steps.

Advantages of Linear Programming Method
Mark, (1998); Onwurah, (2005); highlight some advantages and disadvantages of Linear Programming. Some of the advantages of Linear Programming method are:

i. Scientific Approach to Problem Solving. It is the application of scientific approach to problem solving. Hence it results in a better and true picture of the problems which can then be minutely analyzed and solution ascertained.

ii. Quality of Decision. LP provides practical and better quality of decisions that reflect very precisely the limitation of the system i.e; the various restrictions under which the system must operate for the solution to be optimal. If it becomes necessary to deviate from the optimal path, LP can quite easily evaluate the associated costs or penalty It guaranteed the finding of optimal solution

iii. Evaluation of All Possible Alternatives. Majority of the problems in animal feed formulation are somehow complicated. LP method ensures that all possible solutions are generated, out of which the optimal solution is selected.

iv. Flexibility. LP is flexible mathematical method.

Disadvantages of Linear Programming Method
Although Linear Programming (LP) is a highly successful techniques having wide applications, yet it has some demerits which are as follows:

i. Absence of risk

ii. Linear Relationship: It can only be applied to situations where the given problem can be represented in the form of linear relationship. Hence it is based on implicit assumption that the objective as well as all the constraints or the limiting factors can be stated in the form of linear expression. Many practical problems like feed mix problem can be better expressed with a minimum of quadratic equation.

iii. Constant Value of objective and Constraint Equations. Before a LP technique could be applied to any feed mix problem, the values or the coefficients of the objective and constraints functions must be completely known and be constant over a period of time. If the values change during the period of study, the LP would loose its
iv. Fractional solutions often have no meaning. There is absolutely no certainty that the solution to a LP feed mix problem can always be quantified as an integer quite often. It can give fractional answers which are rounded off to the next integer. Hence, the solution would not be the optimal one.

v. Flexibility Limitation. Once a problem has been properly quantified in terms of objective function and constraint equations and the tools of Linear Programming are applied to it, it becomes very difficult to incorporate any changes in the system arising on account of any change in decision parameter. Hence, it lacks the desired operational flexibility. Reducing the world to a set of linear equations is usually very difficult.

vi. Multiplicity of Goal. The long-term objectives of any farm are not confined to a single goal. Any farm, at any point of time in its operations has a multiplicity of goals or the goals hierarchy- all of which must be attained on a priority wise basis for its long term growth. In a case where farm manager’s goals are multiple and conflicting, the LP method fails.

vii. Degree of Complexity. Many large-scale real life practical problems can be solved by employing LP techniques even with the help of a computer due to high complexity and lengthy calculations involved. Assumptions and approximations are required to be made so that the given problem can be broken down into several smaller problems and, then solved separately. Hence, the validity of the final result, in all such cases, may be doubtful.

2.2 Limitations of Existing Feed Formulation Methods.
Computer allows rapid formulation of rations that meet nutrient specifications at minimum cost. Because of the precision possible with the use of computers, it is tempting to forget that the formula produced is only reliable as the input data given to the computer. Nutritional specifications must be reviewed to take care of changes due to new research findings. Close attention to ingredient quality is essential for reliable formulation. Madueke (2004) while trying to look at the way to solve the problem of an ever increasing animal protein gap in Nigeria, recommended that there should be massive increase in livestock production at lowest possible cost. Though policy programmes in Nigeria Livestock Industry are still centered on the conventional livestock (cattle, sheep, goats, pigs and poultry) , their production has consistently remained low. The reason for this has been the huge capital requirements, high feed costs and poor management (Madubuike et. al. 2003; Mbanasor and Nwosu 2003). Oyenuga (1968) identified poultry as being animal produced in more percentage in Nigeria. Esonu et al (2001) reported that more than 50 percent of Nigeria’s poultry farms have closed down and another 30 percent forced to reduce their production capacity due to high costs of livestock feeds. This livestock feed actually account for 70 to 80 percent of cost of livestock production against the 55 percent to 70 percent earlier reported by Pond and Maner, (Madubuike and Ekenyem, 2001).

3. Material and Methods
Neuro-fuzzy Animal Feed Formulation

Neuro-fuzzy algorithm for animal feed formulation
Enumerated below is the algorithm for the system
Step 1: Start
Step 2: (Select the target vector from the recommended component levels for the animal type to be formulated for, which invariably forms the target vector).
   - Capture the recommended percentage nutrient level for the type of ration to be formulated. Specifically, those to be used as the control parameters.
   - Organize the percentage parameters into a vector.
     The target will generate an input vector \( p = (1 \times m) \) where \( m \) is the number of feed requirement to be satisfied in the feed formulation.
Step 3: (Select the available feed ingredients to be used in the feed formulation).
   - Select the feed ingredients to be used in the formulation

71
- Enter their percentage nutrient contents levels
- Organize these parameters into an m by n vector
  Vector \( q = mxn \)
  where \( m \) is the number of ingredients to be used in the formulation
  \( n \) in the number of the control parameters which is determined by the number of feed
  requirement to be satisfied in the formulation.

**Step 4:** Normalize the input vector \( p \) (using minmax pre-processing function)

**Step 5:** Fuzzify the input vector using sigmoidal membership function

\[
f(x_k, a, b) = \frac{1}{1 + e^{-a(x_k-b)}}
\]
where \( a \) is the maximum value for feed ingredient \( x_k \)
\( b \) is minimum value for feed ingredient \( x_k \)
and \( 1 < k \leq m \)

**Step 6:** Adjust the weight of the elements of the network by training the

i. Network using the Levenberge training algorithm

\[
Qx_{k+1} = x_k - [J^T + \mu I]^{-1} J^T e
\]
where \( x_{k+1} \) is the output of \( (i+1)^{th} \) iteration
\( x_k \) is the output of the previous iteration
\( J \) is the Jacobian matrix that contains the first derivatives of the network
\( J^T \) is the transpose of the Jacobian matrix
\( e \) is the vector of the network errors.
\( \mu \) is a scalar which is usually decreased at each consecutive iterations.

ii. Employ fuzzy multiple conjunctive antecedent inference method to form the inference layer of the system.

\[
\text{IF } x \text{ is } P^{1,1} \text{ AND } P^{1,2} \ldots \text{ AND } P^{1,n} \text{ THEN } y \text{ is } Q^1
\]
\[
\text{IF } x \text{ is } P^{2,1} \text{ AND } P^{2,2} \ldots \text{ AND } P^{2,n} \text{ THEN } y \text{ is } Q^2
\]
\[
\vdots
\]
\[
\text{IF } x \text{ is } P^{n,1} \text{ AND } P^{n,2} \ldots \text{ AND } P^{n,n} \text{ THEN } y \text{ is } Q^m
\]

where \( p^{n,r} \) AND \( p^{n,2} \ldots AND p^{n,m} \) THEN \( y \) is \( Q^m \)

\[
\mu_{P^{n,i}}(x) = \min \{ \mu_{P^{n,1}}(x), \mu_{P^{n,2}}(x), \ldots, \mu_{P^{n,m}}(x) \}
\]

\[ i(x_i) = \frac{\int_{R_{k=1}}^{R_{n}} \mu_{p_k}(x) dx}{\int_{R_{k=1}}^{R_{n}} \mu_{p_k}(x) dx} \]  \( \text{Simulated output} \)

\[ i(x_i) \] is the defuzzified output value of feed ingredient \( X_i \)

**Step 7:** Defuzzify the output of the training (Simulated output) using (minmax post-processing function).

**Step 8:** Generate the percentages combination for the feed formulated for each components \( x_i \) for \( i = 1 \) to \( n \) \( \{x_1, x_2, \ldots, x_n\} \)

**Step 9:** Multiply each \( P(x_i) \) by component digestible nutrients of individual ingredients in the feed \( hu(y_i) \).

\[
P(x_1) \{ hu(y_1), hu(y_2), \ldots, hu(y_m) \}
\]
\[
P(x_2) \{ hu(y_1), hu(y_2), \ldots, hu(y_m) \}
\]
\[
P(x_n) \{ hu(y_1), hu(y_2), \ldots, hu(y_m) \}
\]
where \( h_i(y_i) \) the percentage of the digestible nutrient \( i \) in each feed ingredient.

Step 10: Calculate the percentage nutrient and digestible nutrient contents.

Percentage digestible nutrient is calculated by equation (5)

\[
q_i = \sum_{k=1}^{n} h_i y_i
\]

where \( q_i \) is the total digestible nutrient \( i \) in the formulated feed.

Stop 11: Stop

This study employs the output from the neuro-fuzzy animal feed formulation method in its study against National Registration Council (NRC) standards for chicks feed standard.

The specific research questions in this paper are listed below. They are tested at 0.05 levels of significance.


ii) What is the degree of relationship between the two results i.e. NF & NRC 1994.

To examine the above research question, statistical analysis tools to be employed are:

i) Scatter diagram will be used to depict the direction and the nature of the relationship that exist between NF and NRC 1994.

ii) T- test will be used to examine the nature of the relationship

\[
H_0: \mu_d = 0 \quad vs \quad H_1: \mu_d \neq 0
\]

\[
t_{n-1} = \frac{x - \mu_0}{s/\sqrt{n}}
\]

4. Results and discussion

The output of the neuro-fuzzy system compared with National Registration Council (NRC, 1994) is shown in table 1. Integrity of the system is test by comparing it with the control (NRC 1994). Analysis of the result is done on NCSS 2000 with alpha \( \alpha = 0.05 \).

(i) Plot section

The normal distribution plot of differences in fig 1a indicates normality that exist between the data (treatments).

(ii) Assumptions section: The test of assumption in fig 2 indicates that normality cannot be rejected for the treatments and that 0.889 correlation exist between the treatments.

(iii) T-test section: From fig 3, the p-value for this test is 0.977, which is much greater alpha (a) 0.005. Thus, the conclusion of this hypothesis is acceptance, i.e. there is no difference in the two treatments. (i.e. NF and NRC 1994).

(iv) Descriptive statistics: Fig 4 showed that the mean difference is 3.138375E-02 %, with standard deviation being 4.315441. The 95% interval estimate for the mean difference ranges from -2.268152 to 2.33092.

Advantages of neuro-fuzzy animal feed formulation system.

Some of the advantages of neuro-fuzzy system which neuro-fuzzy animal feed formulation system inherited are as follows:

i. A multi-objective, purpose-driven animal feed formulation method.

ii. It is simpler to use because it involve simple input from the users while the system does the processing (all the complex computations) and produces the desired output to the system users.

iii. It incorporates the knowledge of miller’s expertise into the feed formulation.

iv. It can compound as many target nutrient components as possible with a number of available feed ingredients

v. It combines the feed ingredients within a reasonable affordable limit.

vi. It can be applied for any type of animal feed once the recommended nutrient level and the nutrient contents of the available feed ingredients are known.

Limitation

With the neuro-fuzzy system, the number of targeted feed nutrients contents determines the number of feed ingredients to be employed in the formulation.
References


Thomas S. Ferguson, (). Linear Programming: A Concise Introduction.

Table 1 Output from Neuro-fuzzy (NF) and NRC 1994 for amino acid content in chicks feed.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>NF</th>
<th>NRC (1994)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>0.558</td>
<td>1.4</td>
</tr>
<tr>
<td>Histidine</td>
<td>0.127</td>
<td>0.65</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>0.28</td>
<td>10.18</td>
</tr>
<tr>
<td>Leucine</td>
<td>0.4588</td>
<td>2.2</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.33234</td>
<td>1.22</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>0.3049</td>
<td>1.41</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>0.184</td>
<td>0.79</td>
</tr>
<tr>
<td>Cystine</td>
<td>0.075</td>
<td>0.53</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.1334</td>
<td>0.52</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.2316</td>
<td>0.94</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>0.073</td>
<td>0.39</td>
</tr>
<tr>
<td>Valine</td>
<td>0.3111</td>
<td>1.3</td>
</tr>
<tr>
<td>Crude protein</td>
<td>31.71</td>
<td>23.85</td>
</tr>
<tr>
<td>Ether Extract</td>
<td>16.97</td>
<td>6.5</td>
</tr>
<tr>
<td>Crude Fiber</td>
<td>9.54</td>
<td>8.38</td>
</tr>
<tr>
<td>Metabolizable Energy (Kj/g)</td>
<td>2.749</td>
<td>3.276</td>
</tr>
</tbody>
</table>

Fig 1a. Norm probability plot of difference

(b) Scatter plot of NRC 1994 against NF

(c) Average-difference plot
Assumption | Value | Probability | Decision (5%)  
--- | --- | --- | ---  
Skewness Normality | 1.0936 | 0.274152 | Cannot reject normality  
Kurtosis Normality | 2.2865 | 0.022227 | Reject normality  
Omnibus Normality | 6.4238 | 0.040280 | Reject normality  
Correlation Coefficient | 0.888608 | |  
Fig 2. Test of assumptions about differences  

| Alternative Hypothesis | T-Value | Prob | Decision (5%) | Power (Alpha=.05) | Power (Alpha=.01)  
--- | --- | --- | --- | --- | ---  
C1-C2<>0 | 0.0291 | 0.977177 | Accept Ho | 0.050085 | 0.010025  
C1-C2<0 | 0.0291 | 0.511412 | Accept Ho | 0.047197 | 0.009312  
C1-C2>0 | 0.0291 | 0.488588 | Accept Ho | 0.052934 | 0.010732  
Fig 3. T-test for difference between means  

| Variable | Count | Mean | Deviation | Error of Mean | 95% LCL | 95% UCL  
--- | --- | --- | --- | --- | --- | ---  
C1 | 16 | 4.002384 | 8.705559 | 2.17639 | -0.6364809 | 8.641249  
C2 | 16 | 3.971 | 6.098962 | 1.524741 | 0.7210924 | 7.220908  
Difference | 16 | 3.138375E-02 | 4.315441 | 1.07886 | -2.268152 | 2.33092  
T for Confidence Limits = 2.1314  
Fig 4. Descriptive statistics  


This academic article was published by The International Institute for Science, Technology and Education (IISTE). The IISTE is a pioneer in the Open Access Publishing service based in the U.S. and Europe. The aim of the institute is Accelerating Global Knowledge Sharing.

More information about the publisher can be found in the IISTE’s homepage: http://www.iiste.org

CALL FOR PAPERS

The IISTE is currently hosting more than 30 peer-reviewed academic journals and collaborating with academic institutions around the world. There’s no deadline for submission. **Prospective authors of IISTE journals can find the submission instruction on the following page:** http://www.iiste.org/Journals/

The IISTE editorial team promises to the review and publish all the qualified submissions in a fast manner. All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Printed version of the journals is also available upon request of readers and authors.

**IISTE Knowledge Sharing Partners**

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digital Library, NewJour, Google Scholar