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Neuro-Fuzzy System for Livestock Feed Formulation (*African Poultry*)

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Abstract

This paper develops a neuro-fuzzy algorithm for African poultry feed formulation. The algorithm employs an artificial neural network method for fine-tuning the proportion of individual ingredients in the formulated feed. The algorithm was trained with African feed ingredients composition on MATLAB 2009 platform. Outputs from the system were compared with some available standards and the data analyzed on NCSS 2000. It was discovered that output of the algorithm produced a correlation coefficients of 0.95 and 0.93 for broilers and chick major feed components. At significant level of 0.05 chicks amino acid contents, it produced an f ratio of 0.31 and p value of 0.74 while for layers amino acid content, it produce an f-ratio of 4.66 and p- value of 0.016. A further analysis of output of layer amino acid gave p value of 0.0000037 and T of 4.80978 and p-value 0.11379 and T-value of 1.6273 against the two standards used as bench marks for its validation.

Keywords: *Feed, Neuro-Fuzzy system, Livestock, Nutrients, Digestible Nutrients.*

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I. INTRODUCTION

The value of animal protein in human development cannot be over emphasized. Hence, its sub-optional consumption by a large percentage of Nigerians has become a major concern not only to livestock producers, but also to policy makers (Madubuike, 1992). Protein consumption is important for physical, mental and physiological development of man since it not only supports for growth, mental development and replacement of worn out tissues, but also improves health maintenance and general welbeing. Igben (2000) observed that livestock and its by-products enhance human nutrition, increase the level of employment and improve the capacity of the economy to generate and sustain increased personal income as well as export earnings.

Over the years, many Nigerians have consistently consumed less of animal protein as a result of the increasing costs of animal production with the consequent decrease in animal farming and subsequently animal products availability (Madubuike, 2004). The consequent low livestock products to human population ratio in Nigeria over several years now has been compounded by the ever rising costs of animal feeds occasioned by the already critical competition between man and livestock for feed grains. 1970s disaster in various West African regions which dried up vegetation (source of feed for most livestock particularly ruminants), drastically reduced livestock population (Ademe, 1976), and the Nigerian livestock Industry has yet not fully recovered from the effects of this disaster. The World Health Organization report (2001) asserts that Nigerian population by the year 2000 was 113.0 million with annual growth rate of 2.9% per annum and chicken is the third food of animal origin consumed by the populace. The demand for animal protein is on the increase due to ban on importation of chicken and growth in population. For the industry to meet this demand, research result need to be utilized for improvement in production and productivity (Ogunlade, 2007).

Nigeria feed production is expanding rapidly and poultry feed production accounting for approximately 98% of the total feed production in Nigeria. Between 2000 and 2001, compound feed production jumped from 500,000 tons to 800,000 tons, reflecting the rapid growth in the poultry industry in more recent years. Feed manufacturing in the country can be categorized into any of these groups, namely: Large - scale commercial feed millers, On-farm self-miller and the toll miller. In Nigeria, layer feed constitute the bulk of the production (70%) followed by starter (20%) and finally by broiler diet (10%) (Ali, 2002). Many of the methods employed for animal feed formulation are mathematically intensive, cumbersome, laborious and time consuming.

Traditional linear programming (LP) for feed formulation is used for problems with a single goal, which is usually to minimize the cost of the ration. It is not unusual for a nutritionist to have other feed formulation goals, such as minimizing the nutrient variance, in addition to reducing the cost of production of the feed. However, multiple objectives, although desirable, can be conflicting. Thus, a traditional LP application to a multiple-objective problem may result in an infeasible solution. (Zhang and Roush, 2002)

II. METHODOLOGY

Neuro-fuzzy is an hybrid paradigm that combines that strengths of the two methods (Artificial Neural Network and Fuzzy logic) to complement each other's weaknesses. Giovanna (1998) and Lefteri and Robert (1997) described a neuro-fuzzy network as a fuzzy system with *n*-inputs $X_1, \ldots, x_n$ and *m* outputs $y_1, \ldots. y_m$ that can be represented with the artificial neural network containing five sections, namely: input, fuzzification, inference and defuzzification stage.

2.1 Neuro-fuzzy System 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= (1x 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

- Enter their percentage nutrient contents levels

- Organize these parameters into an m by n vector

Vector *q= m x n*
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

$$f(x_k, a, b) = \frac{1}{1 + e^{-a(x_k - b)}} \quad (1)$$

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

$$Qx_{k+1} = x_k - [J^T J + \mu I]^{-1} J^T e \quad (2)$$

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.
μI 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.

IF *x* is $P^{1,1}$ *AND* $P^{1,2}$ ... *AND* $P^{1,m}$ THEN *y is* Q^1
IF *x* is $P^{2,1}$ *AND* $P^{2,2}$ ... *AND* $P^{2,m}$ THEN *y is* Q^2
:
IF *x* is $P^{n,1}$ *AND* $P^{n,2}$ ... *AND* $P^{n,m}$ THEN *y is* Q^m
where $P^{n,r}$ = $P^{n,1}$ *AND* $P^{n,2}$ ...*AND* $P^{n,m}$

$$\mu p^{n,r}(x) = \min[\mu p^{n,1}(x), \mu p^{n,2}(x), \ldots, \mu p^{n,m}(x)] \quad (3)$$

where $p^{n,i}$ is membership value for nutrient content *n* of feed ingredient *i*
$1 < i \leq m, 1 < n \leq m$

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

$$\text{ʅ}(x_i) = \frac{\int \sum_{k=1}^{n} \mu p_k(x)dx}{\int \sum_{k=1}^{n} \mu p_k(x)dx} \quad (4)$$

where $\text{ʅ}(x_i)$ is the defuzzified output value of feed ingredient x_i.

Step 8: Generate the percentages combination for the feed formulated for each components x_i for i = 1 to n. ʅ(x_1), ʅ(x_2), . ., ʅ(x_n)

Step 9: Multiply each Ƥ(x_1) by component digestible nutrients of individual ingredients in the feed ƕ(y_i).
Ƥ(x_1)*{ ƕ(y_1), ƕ(y_2), . ., ƕ(y_m)}
Ƥ (x_2)*{ ƕ(y_1), ƕ(y_2), . ., ƕ(y_m)}
. . . .
. . . .
Ƥ (x_n)*{ ƕ(y_1), ƕ(y_2), . ., ƕ(y_m)}
where ƕ(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 (10)

$$q_i = \sum_{k=1}^{n} \text{ƕ}y_i \quad (5)$$

where q_i is the total digestible nutrient *i* in the formulated feed.

Stop11: Stop

III. RESULTS AND DISCUSSION

Broilers ration: The network was simulated with African feed ingredients and compared with some available standards to examine its performance for acceptability. Table 1 showed the output from the NF system against Taiwo, (1981)

Table 1: Output of the Neuro-fuzzy Taiwo (1981) for Broilers ration

Ingredients	**NF**	**TAIWO (1981)**
Crude Protein (%)	34.75	23.8
Ether Extracts (%)	1.94	5.23
Crude fiber (%)	1.07	2.9
Nitrogen free extracts (%)	50.38	60.31
Total Ash (%)	4.47	7.76
Metabolizable Energy (Kj/g)	0.222	3.84

Hypothesis1: The hypothesis is working for data presented in table 1
Statement of hypothesis 1
$H_0 = \mu_d = 0$
vs
$H_a = \mu_d \neq 0$
where μ_d is difference between means
Assumptions:
[1] The data are continuous and not discrete.
[2] The data i.e the differences for the marched-pairs, follow a normal probability distribution. And

[3] The sample of pairs is a simple random sample from its population. Each individual in the population has an equal probability of being selected in the sample.
NCSS 2000 employs the equations (6) to (9)

The treatment mean, $\bar{x}$, used in the calculation is given

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (6)$$

Where n is the number of values in the treatment
x_i is the individual values in the treatment
The standard deviation, S, is given as

$$S = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} \qquad (7)$$

and the estimated standard error is, $S_{\bar{x}}$,

$$S_{\bar{x}} = \frac{S}{\sqrt{n}} \qquad (8)$$

Lower and upper confidence limit

$$\bar{x} \pm t_{\alpha/2, n-1} \frac{S}{\sqrt{n}} \qquad (9)$$

where α is the level of significance for the analysis
Result of t-test on NCSS 2000, showed that the treatments were normally distributed and the coefficient of correlation is 0.951952 as shown in figure 2. The means, standard deviation and error of difference is -1.834667, 6.876022 and 2.807124 respectively for confidence limit of 2.5706. The t-test for difference between the two means accepts the null hypothesis at confidence level of 0.05 as shown in figure 3.

Tests of Assumptions about Differences Section

Assumption	Value	Probability	Decision(5%)
Skewness Normality	0.0000		
Kurtosis Normality		1.000000	Cannot reject normality
Omnibus Normality			
Correlation Coefficient	0.951952		

Figure 2: Test of assumptions about differences from NCSS 2000.

Alternative Hypothesis	Prob T-Value	Decision Level (5%)	Power (Alpha=.05)	Power (Alpha=.01)	
C1-C2<>0	-0.6536	0.542245	Accept Ho	0.083746	0.018976
C1-C2<0	-0.6536	0.271122	Accept Ho	0.141023	0.034051
C1-C2>0	-0.6536	0.728878	Accept Ho	0.013223	0.002253

Figure 3: t-test for difference between means from NCSS 2000.

Chicks ration: Table 2 shows the output from the neuro-fuzzy system and Taiwo for chicks ration.

Table 2 Neuro-fuzzy (NF) and Taiwo (1981) Standards for Chicks ration

Ingredients	NF	Taiwo(1981)
Crude protein (%)	31.71	23.85
Ether extracts (%)	16.97	6.5
Crude fiber (%)	9.54	8.38
Nitrogen free extracts (%).		
Total ash (%)		
Metabolizable.Energy (Kj/g)	2.749	2.9

*Hypothesis2:*The hypothesis is working for data presented in table 2
$H_0 = \mu_d = 0$
vs
$H_a = \mu_d \neq 0$
where μ_d is difference between means

As assumptions and the equations (6) to (9) remain as in hypothesis 1, the statistical analysis showed that the two treatments are normally distributed and are at correlation between the pairs is 0.928824 as shown in figure 4. The means, standard deviation and standard error of difference is 4.83475, 5.140352 and 2.807124 respectively for confidence limit of 3.1824. At 0.05 level of significance, the null hypothesis was accepted which showed that the second null hypothesis is acceptable at 0.05 level of significance as reflected in figure 5.

Assumption	**Value**	**Probability**	**Decision(5%)**
Skewness Normality		0.0000	
Kurtosis Normality		1.000000	Cannot reject normality
Omnibus Normality			
Correlation Coefficient		0.928824	

Figure 4: Test of assumptions from NCSS 2000.

T-Test For Difference Between Means Section

Alternative Hypothesis	**Prob T-Value**	**Decision Level (5%)**	**Power (Alpha=.05)**	**Power (Alpha=.01)**	
C1-C2<>0	1.8811	0.156525	Accept Ho	0.262617	0.067361
C1-C2<0	1.8811	0.921737	Accept Ho	0.000655	0.000108
C1-C2>0	1.8811	0.078263	Accept Ho	0.425892	0.124536

Figure 5: T-test for differences between means from NCSS 2000.

Hypothesis3: The means of the treatments shown in table 3 is been statistically compared in this third hypothesis. The statement of hypothesis is that

$H_0 = \mu_d = 0$: There is no significant difference between output from the neuro-fuzzy algorithm and the available standards.

$H_a = \mu_d \neq 0$: at least one of the groups is different.

where μ_d is difference between means

Trace elements for chicks: Table 3 reflcts the output from the NF system, Taiwo 1981 and NRC 1971for trace elements in the chicks ration.

Table 3: Amino acid contents for chicks ration

Ingredients	**NF**	**Taiwo(1981)**	**NRC(1971)**
Arginine	0.558	1.4	1.2
Histidine	0.127	0.65	0.4
Isoleucine	0.28	10.18	0.75
Leucine	0.4588	2.2	1.4
Lysine	0.33234	1.22	1.1
Phenylalanine	0.3049	1.41	0.7
Tyrosine	0.184	0.79	0.6
Cystine	0.075	0.53	0.35
Methonine	0.1334	0.52	0.4
Threonine	0.2316	0.94	0.7
Tryptophan	0.073	0.39	0.2
Valine	0.3111	1.3	0.85
Crude protein	31.71	23.85	20
Ether Extract	16.97	6.5	
Crude Fiber	9.54	8.38	
M E (Kj/g)	2.749	3.276	2.9

A planned Analysis of Variance (ANOVA) was conducted on the data and output is presented in table 4. The planned ANOVA of the data produced an *F* ratio 0.31, probability level of 0.736215 and power of 0.09 at 0.05 level of significance as reflected in the generated ANOVA table (table 4). For the comparisons, the null hypothesis is accepted, (i.e the mean of the treatments are equal).

Table 4: ANOVA table for chicks trace elements

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob. Level	Power (Alpha=0.05)
A (...)	2	29.26137	14.63068	0.31	0.736215	0.095912
S(A)	43	2039.789	47.43695			
Total (Adjusted)	45	2069.05				
Total	46					

* Term significant at alpha = 0.05

A planned Analysis of Variance (ANOVA) was conducted on the data and output is presented in table 5 (amino acid content for layer ration). With 0.05 level of significance the planned ANOVA of the data produced an *F* ratio 4.66 and probability level of 0.018 and power of 0.7359 as reflected in the generated ANOVA table. The null hypothesis is rejected. Further analysis reveal that at $\alpha=0.05$ and MSE= 0.1360905, planned comparison with Taiwo produced $p=0.0000037$ and $T=4.80978$, therefore the two groups (NF and Taiwo) do not have the same mean since $p<\alpha$. A planned comparison of NF and NRC produced $p=0.11379$ and $T=1.6273$. Therefore, the two groups have the same group mean.

Tests of Assumptions Section

Assumption	Test Value	Prob Level	Decision (0.05)
Skewness Normality of Residuals	1.4772	0.139630	Accept
Kurtosis Normality of Residuals	0.2302	0.817957	Accept
Omnibus Normality of Residuals	2.2350	0.327094	Accept
Modified-Levene Equal-Variance Test	2.3275	0.116801	Accept

Figure : NCSS output on the assumptions

Table 5: Amino acid contents of the feed for layer ration

Table 6 Analysis of Variance Table for amino acids in layer feed

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A (...)	2	1.62184	0.81092	4.66	0.018244*	0.735954
S(A)	27	4.697457	0.1739799			
Total (Adjusted)	29	6.319297				
Total	30					

* Term significant at alpha = 0.05

Amino Acids	NF	Taiwo(1981)	NRC (1971)
Arginine	0.487	1.81	0.8
Histidine	0.1214	0.55	
Isoleucine	0.3138	1.78	0.5
Leucine	0.643	1.79	1.2
Lysine	0.265	0.99	0.5
Phenylalanine	0.326	1.08	
Tyrosine	0.251	0.56	
Cystine	0.0282	0.66	0.25
Methonine	0.0711	0.66	0.28
Threonine	0.262	0.7	0.4
Tryptophan	0.037	0.21	0.11
Valine	0.362	1.07	

IV. CONCLUSION

Outcome of the statistical analysis reveal that employment of soft-computing methods can effectively and efficiently cope with feed mix problems. It can also be employed by grass root farmers to boost their productivity with minimized cost.

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Appendix A : Output of planned comparison of amino acid in chicks ration

Planned Comparison: A1

Response: C1,C2,C3

Term A:

Alpha=0.050 Error Term=S(A) DF=43 MSE=47.43695

Comparison Value=-3.138375E-02 T-Value=1.288818E-02 Prob>|T|=0.989777 Decision(0.05)=Accept

Comparison Standard Error=2.435081

Comparison

Group	**Coefficient**	**Count**	**Mean**
C1	-1	16	4.002384
C2	1	16	3.971
C3	0	14	2.253572

Planned Comparison: A2

Response: C1,C2,C3

Term A:

Alpha=0.050 Error Term=S(A) DF=43 MSE=47.43695

Comparison Value=-1.748812 T-Value=0.6938223 Prob>|T|=0.491525 Decision(0.05)=Accept

Comparison Standard Error=2.520548

Comparison

Group	**Coefficient**	**Count**	**Mean**
C1	-1	16	4.002384
C2	0	16	3.971
C3	1	14	2.253572

Appendix B: Output of planned comparison of amino acid in layer ration

Planned Comparison: A1

Response: C1,C2,C3

Term A:

Alpha=0.050 Error Term=S(A) DF=31 MSE=0.1360905

Comparison Value=0.724375 T-Value=4.80978 Prob>|T|=0.000037 Decision(0.05)=Reject Comparison

Standard Error=0.1506046

Comparison

Group	**Coefficient**	**Count**	**Mean**
C1	-1	12	0.2639583
C2	1	12	0.9883333
C3	0	10	0.521

Planned Comparison: A2

Response: C1,C2, C3

Term A:

Alpha=0.050 Error Term=S(A) DF=31 MSE=0.1360905

Comparison Value=0.2570417 T-Value=1.627305 Prob>|T|=0.113796 Decision(0.05)=Accept Comparison Standard Error=0.1579554

Comarison

Group	**Coefficient**	**Count**	**Mean**
C1	-1	12	0.2639583
C2	0	12	0.9883333
C3	1	10	0.521