THE ADEQUATE FEEDING MODEL FOR A FARMED CLARIAS-GYRIEPINUS (CATFISH) USING YATE'S ALGORITHM AND THE D-OPTIMAL DESIGNS

PETER EFEZINO OMOSIONI[1], DENNIS ENEGESELE [2]

[1,2]Department of Statistics, Delta State University of Science and Technology, Ozoro, Delta State

Corresponding author email address: [1] zinomaths2006@yahoo.com [2] den4_js@yahoo.com

ABSTRACT: The adequate feeding models for Clarias-Gyriepinus (Cat-Fish) were studied using the Yate algorithm and D-optimal design. A time frame of one month was used for the experimentation. Four feed types were employed, which serve as the factors for the experiment, namely Vital-Feed (V-Feed), AquaMax (A-feed), BlueCrown (B-feed), and Top-Feed (T-Feed). Analysis of the experiment using the Yate algorithm shows a great variation in the growth of Clarias-Gyriepinus using a combination of a high level of V-Feed, high level of A-feed, high level of B-feed, and low level of T-feed. Also, a full quadratic model that contains all the parameters was considered. The Box-Behnken and the central composite designs were studied for the full quadratic model using the D-optimality criterion. The results show that the D-optimum design for central composite design with the largest determinant produced a better feeding model for the farmed Clarias-Gyriepinus when compared to the Box-Behnsken.

Keywords: *Feeding model, Clarias-gyriepinus, Yate's algorithm, D-Optimal, Box-Behnken design, and Central Composite Design*.

.

Introduction

Aquaculture development has been identified as a national means of complementing the dwindling fish supply from capture fisheries. The increased intensification of culture methods for warm water fish such as tilapia and catfish species has called for balanced rations to satisfy their dietary requirements. Organic and inorganic feeds are important in aquaculture to promote bodybuilding and high yields, particularly under controlled fish culture systems where all nutrients are provided in complete feeds. According to Krichgessner *et al* (1986), the value of supplementary feeds depends on their compositions and the digestibility of the individual feed ingredient. Hence adequate combinations of the various individual feed components would enhance the digestibility and utilization of mixed feeds. Studies have revealed that protein is the most important component of fish feeds and should therefore be sufficiently provided in quantity and quality to ensure protein of high biological value in the formulation of feed which will support optimum fish growth and yield (Hepher *et al.,* 1979). Falaye and Akinyemi (1985) highlighted that the shortage of fish feed constitutes one of the major problems to accelerated fish production in the country. Robison et al (2001) compared different feeding strategies for the pond-raised channel catfish (once daily, every other day (EOD), and once daily to half satiation ETD). They reported that maximum production was achieved by feeding to apparent satiation daily. Further, they observed a 50% and 65% increase in feed consumption (on days feed) of fish fed EOD or ETD, respectively, compared with those fed daily. These data are partly supported by those of Li *et al* (2004, 2006) and Omosioni and Iwundu (2010) in that production tends to be highest when catfish are fed daily to apparent satiation, and feed conversion ratio (FRC) is improved than when fish are fed less daily. The primary difference in these studies was the size of the fish used. Robinson *et al* (2001) used larger fish (270-320 grams) whereas Li, *et al* (2004) used fish of about 93 grams, Li *et al* (2006) used 64-gram fish and Omosioni and Iwundu (2010) used fish of (500-800) grams. An increase in fish harvest per unit area of production can only be achieved by intensification of the culture methods, which is accompanied by increased addition of balanced supplementary diets to the system. Maduabuchi *et al* (2024) studied the effect of different diets containing varying inclusion levels of Moringa oleifera leaf meal on growth, mineral composition and meat quality of the edible land snails Archachatina marginata and Achatina fulica. Onu et al (2022) studied estimation of Parameters and Optimality of Second-Order Spherical Designs Using Quadratic Function Relative to Non-Spherical Face centered CCD. The study revealed that the sum of square error of the non-spherical face centred CCD is zero (0) for radial point of n=5 with 1 centre point and this result is seen to be a misleading result, because, no process is 100%. While the sum of square error of the spherical designs with axial distance of 1.0 gave minimal sum of square errors and the spherical designs with axial distance of 1.414 gave very large sum of square error. The Grand mean of the spherical and the non-spherical designs were equal or approximately equal for radial point of n=5 for centre points 1-10 inclusive. But as the radial distance increases above 5, the Grand mean of the non-spherical CCD differs significantly from those of the spherical designs. The study suggests that the non-spherical second order design is inferior to their spherical second order design counterparts. The spherical designs with axial distance of 1.414 (equiradial and circumscribed CCD) have better D-optimality, , A-optimality and T-optimality than the non-spherical face centred CCD, while, the spherical designs with axial distance of 1.0 (equiradial and inscribed) has inferior D-optimality, A-optimality and T-optimality compared to the non-spherical face centred CCD with axial distance of 1.0. Oyejola and Nwanya (2015) carried out a comparative study of five varieties of Central Composite design (SCCD, RCCD, OCCD, Slope-R, FCC) in Response Surface Methodology (RSM) were evaluated using the D, A, G and IV-optimality criteria. They observed that replicating the star points tends to reduce the D and G-optimality criteria of the CCDs (SCCD, RCCD, OCCD, Slope-R, and FCC) in all the factors that were considered while it is not so for A-optimality criterion. In IV-optimality, the CCDs are relatively the same both when the center points and axial portion are increased. The FDS plots indicates that the CCDs maintain relatively low and stable SPV when the star points are replicated with increased center points. Safina *et al* (2012) studied the effect of three different feed types on growth performance and survival of African Catfish Fry (Clarias gariepinus) reared in a Hatchery. Their results demonstrate that after the 7 days of feeding using rotifers, Artemia is the best feed for increasing growth of Clarias gariepinus. Under some economic circumstances, catfish farmers may feed with low-quality feed to reduce costs and minimize economic losses. It is on this basis we consider conducting a four factors factorial experiment using Yate's Algorithm, Box-Behnken design, and Central Composite design to know which feed combination is best suited to produce good results.

Materials and Methods

The data for this research work were obtained from a simply designed 2^4 factorial experiment. The 2^4-factorial experiment was conducted to evaluate the effect of the treatment combination on the growth of catfish. Four sizes of catfish – averaging 20, 25, 30, and 35 grams per fish – were stocked into 16 ponds with each pond measuring 2x2 meter square. The duration of the experiment was one month. Each fish was fed to apparent satiation with a commercial – 45% protein feed. The four randomly selected feed types namely V-feed, A-feed, B-feed, and T feed were each at two – levels, namely low and high levels. The low level of the factor is signified by the use of 5 grams of the feed while the high level of the factor is signified by the use of 10 grams of the feed. Feeds were distributed into each pond manually and the fish were allowed to eat as much as they would consume in 5 minutes to achieve apparent satiation. The fish were fed twice daily 7.00 am and 5.00 pm and the amounts of feeds consumed by the fish in each pond were recorded daily. Observation of the body weight and the length of individual fish were taken weekly for one month using two standard scales and a measuring tape. Data on body weight were analyzed using analysis of variance, graphical techniques, and the D-optimal criteria for testing Box-Behnken and Central Composite Designs.

Table 1: Treatment Combination for Types of Fish and Response

S/N	TREATMENT	TREATMENT COMBINATION	FISH 1	FISH 2	FISH 3	FISH 4	RESPONSE
1	(1)	$V_L A_L B_L T_L$	22	40	35	70	167
2	*a*	$V_H A_L B_L T_L$	25	45	50	65	185
3	*b*	$V_L A_H B_L T_L$	26	55	60	55	196
4	*ab*	$V_H A_H B_L T_L$	29	50	59	68	206
5	*c*	$V_L A_L B_H T_L$	30	43	50	63	186
6	*ac*	$V_H A_L B_H T_L$	28	60	65	80	233
7	*bc*	$V_L A_H B_H T_L$	32	59	70	79	240
8	*abc*	$V_H A_H B_H T_L$	25	67	69	81	242
9	*d*	$V_L A_L B_L T_H$	20	44	50	69	183
10	*ad*	$V_H A_L B_L T_H$	28	56	64	72	220
11	*bd*	$V_L A_H B_L T_H$	27	62	60	70	219
12	*abd*	$V_H A_H B_L T_H$	30	58	63	70	221
13	*cd*	$V_L A_L B_H T_H$	29	60	62	72	223
14	*acd*	$V_H A_L B_H T_H$	34	65	75	120	294
15	*bcd*	$V_L A_H B_H T_H$	28	59	68	90	245
16	*abcd*	$V_H A_H B_H T_H$	32	65	73	94	254

KEY: V = V FEED, A = A- FEED, B = B-FEED, T = T-FEED, H = HIGH LEVEL, L = LOW LEVEL

Data analysis

We employ the Yates' algorithm for the analysis of variance we also present some graphical analysis. Considering the data in Table 1, columns designated Fish 1, Fish 2, Fish 3, and Fish 4 are redesignated, Replicate I, Replicate II, Replicate III, and Replicate IV respectively, in Table 2. The column labeled "Response" contains the total of all observations under the respective treatment combinations. Since there are four factors in the experiments, we shall create four columns labeled Column 1, Column 2, Column 3, and Column 4. The first half of column 1 is obtained by adding the responses in adjacent pairs. The second half of column 1 is obtained by changing the sign of the first entry in each pair in the response column and adding the adjacent pairs. Column 2 is obtained from column 1 in the same way as column (1) is obtained from the response column. Column (3) is obtained from column (2) and column (4) is obtained from column (3) similarly.

Table 2 below shows the estimates of effects and Sum of Squares Using Yates' Algorithm

using $n=4$, $k=4$ and $N=64$

$$(n-1)\,2^k = 48$$

$$n2^k = 64$$

S/N	TRT	TRT COMB	RES	C0l (1)	COL (2)	COL (3)	COL(4) (K)	ESTIMATE OF EFFECTS $col(k) \div (n-1)\,2^k$	ESTIMATE OF SUM OF SQUARES $col(k)^2 \div n2^k$
1	(1)	$V_L A_L B_L T_L$	187	522	1279	3026	6796	–	–
2	a	$V_H A_L B_L T_L$	335	757	1747	3770	460	9.85	3306.25
3	b	$V_L A_H B_L T_L$	325	866	1696	268	446	9.29	3100.06
4	ab	$V_H A_H B_L T_L$	432	881	2074	192	32	0.67	16.00
5	c	$V_L A_L B_H T_L$	456	788	225	250	846	17.62	11183.06
6	ac	$V_H A_L B_H T_L$	410	908	43	196	–26	–0.54	10.56
7	bc	$V_L A_H B_H T_L$	396	999	18	94	–264	–5.5	1089
8	abc	$V_H A_H B_H T_L$	485	1075	174	–62	314	6.54	1548.56
9	d	$V_L A_L B_L T_H$	399	148	235	468	744	15.5	8649
10	ad	$V_H A_L B_L T_H$	389	107	15	378	–76	–1.50	90.25
11	bd	$V_L A_H B_L T_H$	440	–46	120	–182	–54	–1.13	45.56
12	abd	$V_H A_H B_L T_H$	468	89	76	156	–156	–3.25	380.25
13	cd	$V_L A_L B_H T_H$	431	–10	–41	–220	–90	–1.88	126.56
14	acd	$V_H A_L B_H T_H$	568	28	135	–44	330	6.88	1701.56
15	bcd	$V_L A_H B_H T_H$	519	137	38	176	–264	–5.50	1089

Table 2: Estimates of Effect and Sum of Squares

16	*abcd*	$V_H A_H B_H T_H$	556	37	−100	138	−38	−0.79	22.56

Hence,

From table 2 above SS_T and SS_E are obtained thus:

$$SS_\mu = \frac{\sum y_{ij}^2}{N} = \frac{6796^2}{64} = 721650.25$$

$$SS_T = 22^2 + 40^2 + ...+148^2 + 290^2 - SS_\mu$$

$$= 1074645 - 721650.25$$

$$= 352994.95$$

$$SS_E = SS_T - SS_{ABCD} - SS_{BCD} - ...... - SS_B - SS_A$$

$$= 352994.95 - 3306.25 - 3100.06 - .... - 1089 - 22.56$$

$$= 321841.19$$

Table 3: ANALYSIS OF VARIANCE(ANOVA)

SV	*df*	*SS*	*MS*	$F - ratio$
TRT A	1	600.25	600.25	1.69
TRT B	1	272.25	272.25	0.76
TRT C	1	1600	1600	4.49
TRT D	1	631.27	631.27	1.77
INTER AB	1	351.56	351.56	0.99
INTER AC	1	60.06	60.06	0.17
INTER AD	1	27.56	27.56	0.08
INTER BC	1	72.25	72.25	0.20
INTER BD	1	138.06	138.06	0.39

INTER CD	1	10.56	10.56	0.03
INTER ABC	1	64	64	0.18
INTER ABD	1	30.25	30.25	0.08
INTER ACD	1	6.25	6.25	0.02
INTER BCD	1	130.06	130.06	0.37
INTER ABCD	1	1.56	1.56	0.004
ERROR	48	22789.31	356.08	–
TOTAL	63	26785.75	–	–

$f_{1,48}0.05 = 4.17,\ f_{1,48}0.1 = 2.88$

*Significant at 5% level

**Significant at 10% level

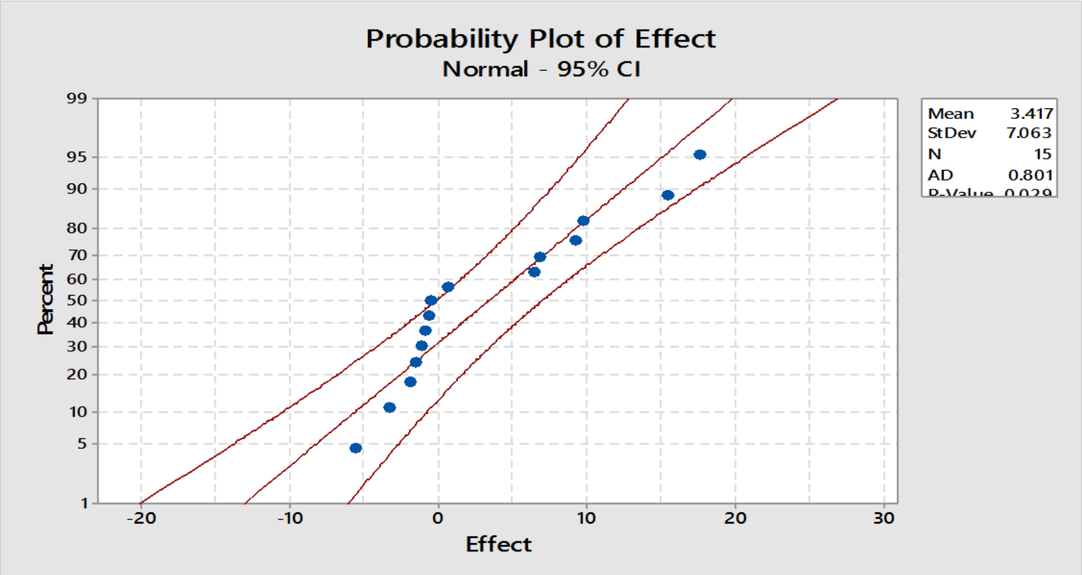

Figure 1: Normal Probability plot for Effect of Feed Type

The p-value of 0.029 indicates that the effects are statistically significant. From the normal probability plot of effects, we see that the effects that seem to be positive are the treatment *a*, *b*, *c*, and *d* and the interaction *ab*, *abc*, and *acd*. These effects have a positive impact on the growth of the catfish

BOX-BEHNKEN DESIGN FOR FOUR FACTORS

The design model is:

$$y = \beta_0 + \beta_1 V + \beta_2 A + \beta_3 B + \beta_4 T + \beta_{12} VA + \beta_{13} VB + \beta_{14} VT + \beta_{23} AB + \beta_{24} AT + \beta_{34} BT + \beta_{11} V^2 + \beta_{22} A^2 + \beta_{33} B^2 + \beta_{44} T^2 + e$$

β_0 = represent the grand mean

β_1= coefficient of V

β_2 = coefficient of A

β_3 = coefficient of B

β_4 = coefficient of T

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_{12} x_{12} + \beta_{13} x_{13} + \beta_{14} x_{14} + \beta_{23} x_{23} + \beta_{24} x_{24} + \beta_{34} x_{34} + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{44} x_4^2 + \varepsilon$$

The design matrix resulting from the full quadratic model is given as

$$X = \begin{bmatrix}
1 & 2 & 2 & 3 & 3 & 4 & 6 & 6 & 6 & 6 & 9 & 4 & 4 & 9 & 9 \\
1 & 2 & 3 & 3 & 2 & 6 & 6 & 4 & 9 & 6 & 6 & 4 & 9 & 9 & 4 \\
1 & 2 & 2 & 1 & 1 & 4 & 2 & 2 & 2 & 2 & 1 & 4 & 4 & 1 & 1 \\
1 & 3 & 2 & 3 & 2 & 6 & 9 & 6 & 6 & 4 & 6 & 9 & 4 & 9 & 4 \\
1 & 2 & 3 & 1 & 2 & 6 & 2 & 4 & 3 & 6 & 2 & 4 & 9 & 1 & 4 \\
1 & 3 & 2 & 2 & 1 & 6 & 6 & 3 & 4 & 2 & 2 & 9 & 4 & 4 & 1 \\
1 & 1 & 3 & 2 & 2 & 3 & 2 & 2 & 6 & 6 & 4 & 1 & 9 & 4 & 4 \\
1 & 2 & 2 & 1 & 3 & 4 & 2 & 6 & 2 & 6 & 3 & 4 & 4 & 1 & 9 \\
1 & 1 & 1 & 2 & 2 & 1 & 2 & 2 & 2 & 2 & 4 & 1 & 1 & 4 & 4 \\
1 & 1 & 2 & 2 & 3 & 2 & 2 & 3 & 4 & 6 & 6 & 1 & 4 & 4 & 9 \\
1 & 1 & 2 & 1 & 2 & 2 & 1 & 2 & 2 & 4 & 2 & 1 & 4 & 1 & 4 \\
1 & 2 & 2 & 2 & 2 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 \\
1 & 2 & 3 & 2 & 1 & 6 & 4 & 2 & 6 & 3 & 2 & 4 & 9 & 4 & 1 \\
1 & 3 & 2 & 2 & 3 & 6 & 6 & 9 & 4 & 6 & 6 & 9 & 4 & 4 & 9 \\
1 & 2 & 1 & 2 & 3 & 2 & 4 & 6 & 2 & 3 & 6 & 4 & 1 & 4 & 9 \\
1 & 3 & 1 & 2 & 2 & 3 & 6 & 6 & 2 & 2 & 4 & 9 & 1 & 4 & 4 \\
1 & 1 & 2 & 3 & 2 & 2 & 3 & 2 & 6 & 4 & 6 & 1 & 4 & 9 & 4 \\
1 & 2 & 1 & 3 & 2 & 2 & 6 & 2 & 3 & 2 & 6 & 4 & 1 & 9 & 4 \\
1 & 1 & 2 & 2 & 1 & 2 & 2 & 1 & 4 & 2 & 2 & 1 & 4 & 4 & 1 \\
1 & 2 & 2 & 2 & 2 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 \\
1 & 3 & 3 & 2 & 2 & 9 & 6 & 6 & 6 & 6 & 4 & 9 & 9 & 4 & 4 \\
1 & 2 & 2 & 3 & 1 & 4 & 6 & 2 & 6 & 2 & 3 & 4 & 4 & 9 & 1 \\
1 & 2 & 2 & 2 & 2 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 \\
1 & 2 & 1 & 2 & 1 & 2 & 4 & 2 & 2 & 1 & 2 & 4 & 1 & 4 & 1 \\
1 & 3 & 2 & 1 & 2 & 6 & 3 & 6 & 2 & 4 & 2 & 9 & 4 & 1 & 4 \\
1 & 2 & 1 & 1 & 2 & 2 & 2 & 4 & 1 & 2 & 2 & 4 & 1 & 1 & 4 \\
1 & 2 & 3 & 2 & 3 & 6 & 4 & 6 & 6 & 9 & 6 & 4 & 9 & 4 & 9 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}$$

The transpose of the design matrix is given

Columns 1 through 16

$$X^T = \begin{bmatrix}
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
2 & 2 & 2 & 3 & 2 & 3 & 1 & 2 & 1 & 1 & 1 & 2 & 2 & 3 & 2 & 3 \\
2 & 3 & 2 & 2 & 3 & 2 & 3 & 2 & 1 & 2 & 2 & 2 & 3 & 2 & 1 & 1 \\
3 & 3 & 1 & 3 & 1 & 2 & 2 & 1 & 2 & 2 & 1 & 2 & 2 & 2 & 2 & 2 \\
3 & 2 & 1 & 2 & 2 & 1 & 2 & 3 & 2 & 3 & 2 & 2 & 1 & 3 & 3 & 2 \\
4 & 6 & 4 & 6 & 6 & 6 & 3 & 4 & 1 & 2 & 2 & 4 & 6 & 6 & 2 & 3 \\
6 & 6 & 2 & 9 & 2 & 6 & 2 & 2 & 2 & 2 & 1 & 4 & 4 & 6 & 4 & 6 \\
6 & 4 & 2 & 6 & 4 & 3 & 2 & 6 & 2 & 3 & 2 & 4 & 2 & 9 & 6 & 6 \\
6 & 9 & 2 & 6 & 3 & 4 & 6 & 2 & 2 & 4 & 2 & 4 & 6 & 4 & 2 & 2 \\
6 & 6 & 2 & 4 & 6 & 2 & 6 & 6 & 2 & 6 & 4 & 4 & 3 & 6 & 3 & 2 \\
9 & 6 & 1 & 6 & 2 & 2 & 4 & 3 & 4 & 6 & 2 & 4 & 2 & 6 & 6 & 4 \\
4 & 4 & 4 & 9 & 4 & 9 & 1 & 4 & 1 & 1 & 1 & 4 & 4 & 9 & 4 & 9 \\
4 & 9 & 4 & 4 & 9 & 4 & 9 & 4 & 1 & 4 & 4 & 4 & 9 & 4 & 1 & 1 \\
9 & 9 & 1 & 9 & 1 & 4 & 4 & 1 & 4 & 4 & 1 & 4 & 4 & 4 & 4 & 4 \\
9 & 4 & 1 & 4 & 4 & 1 & 4 & 9 & 4 & 9 & 4 & 4 & 1 & 9 & 9 & 4
\end{bmatrix}$$

Columns 17 through 28

$$X^T = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 2 & 1 & 2 & 3 & 2 & 2 & 2 & 3 & 2 & 2 & 0 \\ 2 & 1 & 2 & 2 & 3 & 2 & 2 & 1 & 2 & 1 & 3 & 0 \\ 3 & 3 & 2 & 2 & 2 & 3 & 2 & 2 & 1 & 1 & 2 & 0 \\ 2 & 2 & 1 & 2 & 2 & 1 & 2 & 1 & 2 & 2 & 3 & 0 \\ 2 & 2 & 2 & 4 & 9 & 4 & 4 & 2 & 6 & 2 & 6 & 0 \\ 3 & 6 & 2 & 4 & 6 & 6 & 4 & 4 & 3 & 2 & 4 & 0 \\ 2 & 2 & 1 & 4 & 6 & 2 & 4 & 2 & 6 & 4 & 6 & 0 \\ 6 & 3 & 4 & 4 & 6 & 6 & 4 & 2 & 2 & 1 & 6 & 0 \\ 4 & 2 & 2 & 4 & 6 & 2 & 4 & 1 & 4 & 2 & 9 & 0 \\ 6 & 6 & 2 & 4 & 4 & 3 & 4 & 2 & 2 & 2 & 6 & 0 \\ 1 & 4 & 1 & 4 & 9 & 4 & 4 & 4 & 9 & 4 & 4 & 0 \\ 4 & 1 & 4 & 4 & 9 & 4 & 4 & 1 & 4 & 1 & 9 & 0 \\ 9 & 9 & 4 & 4 & 4 & 9 & 4 & 4 & 1 & 1 & 4 & 0 \\ 4 & 4 & 1 & 4 & 4 & 1 & 4 & 1 & 4 & 4 & 9 & 0 \end{bmatrix}$$

The normalized Information matrix is given as

$$M = \frac{X^T X}{B}$$

D-OptimalityCriteria:

The D-Optimal criterion deals with a good model parameter estimation. A D-optimal design is a design where the determinant of the moment matrix $M = \frac{X^T X}{B}$ is maximized over all designs where X represents the design matrix associated with the design and X^T represents its transpose and B is the number of parameters in the model. The determinant of the normalized information matrix is given as;

T= det(M)

T = 1.8891e+14

CENTRAL COMPOSITE DESIGN FOR FOUR-FACTOR USING FULL QUADRATIC MODEL

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_{12} x_{12} + \beta_{13} x_{13} + \beta_{14} x_{14} + \beta_{23} x_{23} + \beta_{24} x_{24} + \beta_{34} x_{34} + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{44} x_4^2 + \varepsilon$$

The information matrix resulting from the design is given as

$$X = \begin{bmatrix} 1 & 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 4 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & -2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 4 & 0 \\ 1 & -1 & 1 & 1 & 1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 4 & 0 & 0 & 0 \\ 1 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 4 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 4 & 0 & 0 & 0 \\ 1 & 1 & -1 & -1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Row 16 through 31

$$X = \begin{bmatrix}
1 & -1 & -1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & -1 & 1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 \\
1 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 4 & 4 & 0 \\
1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & -2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 4 & 4 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 \\
1 & 0 & 0 & 0 & -2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 4 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}$$

The transpose of the information matrix

$$X^T = \begin{bmatrix}
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
0 & -1 & 0 & -1 & -2 & 0 & 0 & 2 & 1 & -1 & -1 & 1 & 1 & 0 & 0 & -1 \\
0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & -1 & 1 & -1 & 1 & 1 & 0 & 0 & -1 \\
0 & -1 & -2 & 1 & 0 & 2 & 0 & 0 & -1 & -1 & -1 & -1 & -1 & 0 & 0 & 1 \\
2 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & -1 & 1 & -1 & 1 & 0 & 0 & 1 \\
0 & -1 & 0 & -1 & 0 & 0 & 0 & 0 & -1 & -1 & 1 & 1 & 1 & 0 & 0 & 1 \\
0 & 1 & 0 & -1 & 0 & 0 & 0 & 0 & -1 & 1 & 1 & -1 & -1 & 0 & 0 & -1 \\
0 & -1 & 0 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & -1 & -1 & 1 & 0 & 0 & -1 \\
0 & -1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & -1 & 1 & -1 & -1 & 0 & 0 & -1 \\
0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 & 1 & 0 & 0 & -1 \\
0 & -1 & 0 & 1 & 0 & 0 & 0 & 0 & -1 & 1 & -1 & 1 & -1 & 0 & 0 & 1 \\
0 & 1 & 0 & 1 & 4 & 0 & 0 & 4 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 1 \\
0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 1 \\
0 & 1 & 4 & 1 & 0 & 4 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 1 \\
4 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 1
\end{bmatrix}$$

Columns 17 through 31

$$X^T = \begin{bmatrix}
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 0 & -1 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
-1 & 0 & -1 & 1 & 2 & -1 & -1 & 1 & 0 & -2 & 0 & 0 & -1 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & -1 & 1 & 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
1 & 0 & -1 & -1 & 0 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & -1 & -2 & 0 \\
-1 & 0 & 1 & 1 & 0 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
1 & 0 & -1 & 1 & 0 & -1 & 1 & 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
1 & 0 & 1 & -1 & 0 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
-1 & 0 & -1 & 1 & 0 & 1 & -1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
-1 & 0 & 1 & -1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
1 & 0 & -1 & -1 & 0 & 1 & -1 & 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 1 & 4 & 1 & 1 & 1 & 0 & 4 & 0 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 1 & 4 & 1 & 1 & 1 & 0 & 4 & 0 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 4 & 0
\end{bmatrix}$$

Multiplying X transpose and X and normalizing, that is, $M = \dfrac{X^T X}{B}$, we have

$$M' = \frac{X^T X}{B}$$

$$M' = \begin{bmatrix} 31 & 1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & 23 & 23 & 31 & 23 \\ 1 & 23 & 1 & 1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & 1 & 23 & -1 & 1 & 3 & 3 & -1 & -1 & 3 & 3 & -1 & -1 & -1 & -1 \\ -1 & 1 & -1 & 23 & 1 & 3 & 3 & -1 & -1 & 3 & 3 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & 1 & 23 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & 1 & 3 & 3 & 1 & 15 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -1 & 1 & 3 & 3 & 1 & -1 & 15 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -1 & 1 & -1 & -1 & 1 & -1 & -1 & 15 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -1 & 1 & -1 & -1 & 1 & -1 & -1 & -1 & 15 & -1 & -1 & -1 & -1 & -1 & -1 \\ -1 & 1 & 3 & 3 & 1 & -1 & -1 & -1 & -1 & 15 & -1 & -1 & -1 & -1 & -1 \\ -1 & 1 & 3 & 3 & 1 & -1 & -1 & -1 & -1 & -1 & 15 & -1 & -1 & -1 & -1 \\ 23 & 1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & 47 & 15 & 15 & 15 \\ 23 & 1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & 15 & 47 & 47 & 15 \\ 31 & 1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & 15 & 47 & 79 & 15 \\ 23 & 1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & 15 & 15 & 15 & 47 \end{bmatrix}$$

A D-optimal design is one in which the determinant of the moment matrix

$M = \dfrac{X^T X}{B}$ is maximized over all the designs. Therefore,

$$\text{Det(M)} = Det\left(\frac{X^T X}{B}\right) = 4.1100e{+}19$$

DISCUSSION OF RESULTS

Table 1 above shows that the treatment ACD with treatment combination has the $V_H A_L B_H T_H$ highest response rate (294). This implies that the catfish will have a greater yield having these feeding combinations. The average growth of fish as measured by its weight is highest using a high level of Vital feed, a Low level of Aquamax feed, a high level of Bluecrown feed, and a high level of Top feed. The estimates of effect and the sum of squares in Table 2 also show that the treatment combination $V_H A_L B_H T_H$ has a higher value of response (568). Treatment C has a higher estimate of the sum of squares (11183.06). this implies that the treatment has greater variability in the treatment combination. Table 2 also shows that the effects that is negative have no significant effect on the growth of the catfish. The analysis of variance in Table 3 shows that treatment C is significant (4.49) at a 5% level of significance.

The treatment combination ACD in Table 3 is not significant as the f-ratio does not exceed the critical value. This implies that the treatment effect are identical even though treatment C has greater variability

The overall performance using the Yates' algorithm shows that to maximize the growth of pond-raised catfish feeds constituting this combination: High level of Vital feed, Low level of Aquamax feed, high level of Bluecrown feed, and high level of Top feed.

Should be adopted.

The D-optimal design of the center composite design reveals a more adequate performance since the determinant of the dispersion matrix Det(M) = $Det\left(\frac{X^T X}{B}\right)$= 4.1100e+19 is higher than the determinant of the Box Behnken design Det(M) = $Det\left(\frac{X^T X}{B}\right)$= 1.8891e+14.

Conclusion

A combination of feed types that is adequate for catfish production has been investigated. The combination gives the fish producer the chance to feed the fish from a variety of feeds. The analysis of the experiment reveals a great difference in the weight of catfish subjected to various feed combinations; the feed combination with a High level of Vital feed, Low level of Aquamax feed, high level of Bluecrown feed, and high level of Top feed. Should be adopted for optimum productivity.

Recommendation

The Box-Behnken and the center composite design reveal a great deal of the best design that maximizes the information on the weight of pond-raised catfish with the center composite showing more adequate results. It is hereby, recommended that further research work be carried out to produce those points that maximize the weight of the fish using the CCD.

References

1. Falaye, A.E, and Akinyemi (1985) "The status of Aquaculture in Nigeria" Proceeding of the consultative workshop on village level aquaculture Development in Africa. Freetown, Sierra leone
2. Hepher,B. Sandbank, E. and Shelef, G.(1979) " Alternative protein sources for warm water fish diets" Proc. World Symp. On finfish nutrition and fish feed technology Hamrug. 20-23 June 1978 vol1. Berlin 1978, 328-337

3. Kirchgessiner,M. Kurzinger, H. and Schwarz,F.J.(1986) "Digestibility of crude nutrients in different feeds and estimation of their energy conent for carp(Cyprinus Carpio)" aquaculture Society.

4. Li, M. H, E. H. Robison, D. F. Oberie, and B.G. Boswort (2006) "*Effect* of dietary protein concentration and feeding regimen on Channel Catfish/ctalurus puntatus production*" Journal of the World Aquaculture Society*.

5. Li, M. H, E. H. Robison, B. B. Manning and B.G *Boswort (2004) "*Effect of dietary protein concentration production characteristics of pond-raised channel catfish feed once daily or once every other day to satiation-North*" America Journal of Aquaculture 66:184-190*

6. Maduabuchi Inwele Amobi, Amara Chibuzo Aamazodo,Bede Izuchukwu Ezewudo and Valentine Obinna Opkoko(2024)."The effect of different diets containing varying inclusion levels of Moringa oleifera leaf meal on growth, mineral composition and meat quality of the edible land snails". Journal of Agriculture and Rural Development in the Tropics and Subtropics Vol. 125 No. 1 (2024) 9–19.

7. Onu, O. H., Ijomah, M. A., & Osahogulu, D.J. (2022). "Estimation of parameters and optimality of second-order spherical designs using quadratic function relative to the non-spherical face centred CCD". *Asian Journal of Probability and Statistics, 18*(3), 23-37. https://doi.org/10.9734/ajpas/2022/v18i330449.

8. Oyejola, B. A., & Nwanya, J. C. (2015). "Selecting the right Central Composite Design". *International Journal of Statistics and Applications*, *5*(1), 21-30. doi: 10.5923/j.statistics.20150501.04.

9. P. E. Omosioni and M. P. Iwundu (2010). "The effect of feed type on the growth of catfish(Claria-Gariepinus) using a 2^k factorial design" *Scientia Africana, Vol. 11 (No.2), December 2012. Pp 65-73 © Faculty of Science, University of Port Harcourt, Printed in Nigeria.*

10. Robinson, E.H., Li, M.H. and Manning, B.B. (2001) A practical guide to nutrition, feeds, and feeding of channel catfish (second revision). Mississipi Agri-cultural and Forestry Experimental Station Bulletin 1113, Office of Agricultural Communications, Mississipi.

11. Safina Musa, Christopher Mulanda Aura, Charles C. Ngugi and Rodrick Kundu (2012). "The effect of three different feed types on growth, performance and survival of Africa catfish fry (clarias-gariepinus) reared in hatchery". International research network. ISRN Zoology, Vol2012, Article ID: 861364, 6pages