Factor Analysis of Poultry Birds De-Feathering Machines

*[1]Kazeem A. Bello, [2]Olayinka M. Tawose, [1]Abdulrahman Adama and [1]Bukola O. Bolaji
[1]Department of Mechanical Engineering, Federal University Oye-Ekiti, Nigeria
[2]Department of Animal Production and Health, Federal University Oye-Ekiti, Nigeria
{kazeem.bello | olayinka.tawose | bukola.bolaji}@fuoye.edu.ng | abdulrahmanadama24@gmail.com

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ORIGINAL RESEARCH

Abstract- Some concerns had been expressed over the success rate of the De-feathering machine (DM) in Nigeria. Therefore, it is imperative to evaluate DM in selected poultry farms in Ekiti State, Nigeria, and consider the factors that inhibit their viability. This study seeks to verify the success rate and identify factors that pose challenges to DM and provide a solution to their intercorrelations. Kendall Coefficient of Concordance (KCC) and Principal Component Analysis (PCA) was the design framework used to investigate the identified factors that influence DM. The KCC was used to analyse the data matrix generated by 12 Judges who ranked the twenty-eight identified factors that influenced DM in ascending order, upon which basis an index of concordance in ranking among the judges was computed as w = 0.70. PCA was used to further analysed questionnaires crafted with the twenty-eight well-ordered factors, purposively selected, using statisticsXL version 2021.2 software. Also, the result obtained by PCA indicates that factor reduction was achieved from twenty-eight variables to seven clusters using a scree plot graph. Furthermore, Cost of Material cluster 5 (consisting of dual factors; 'stainless steel' and 'material selection') wielded the highest factors loading of 0.847 and 0.779 respectively. This study has helped to justify unsatisfactory DM operating costs among poultry farmers in Nigeria and bukola.bolaji@fuoye.edu.ng clarify challenges associated with the high cost of material selection in DM design.

Keywords- De-feathering machine, material selection, poultry birds, principal component analysis, reliability.

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1 INTRODUCTION

The progressive patronage received by local poultry producers reduced the dependence on foreign poultry products and promote the foreign trade balance until the advent of the recent high cost of feather plucking machines due to the high foreign exchange rate (Casnor & Gavino, 2022). Therefore, there is a need to innovatively study the feather plucking machine process and devise a scientific method to produce a low-cost feather plucking machine. The effort to fabricate a low-cost poultry bird feathering plucking machine for a small-scale farm and domestic use remained a daunting challenge (Omoniyi et al., 2019). Despite the awareness and huge investment in poultry farms in recent times, there is no sufficient significant positive achievement in poultry products.

This research work is to provide a lasting solution to poultry birds' de-feathering challenges in other to achieve an economic balance sheet and ease of doing business. Part of the problem affecting the poultry business could be attributed to the high cost of feather plucking machines on the one hand, and the dearth of basic infrastructure facilities as well as failure to recognize customer preference on the other (Waghamare, Popalghat, Londhe, Deshmukh, & Khobe, 2021). This study focuses on identifying numerous variables that impact on poultry de-feathering process, and investigates how eliminating those problems can lead to the low cost of feathering plucking machine fabrication for sustainable food security.

Poultry is defined as domestic birds which are raised for meat or eggs, examples of poultries are a goose, turkey, chicken, duck, goose, and guinea fowl. The appreciably increased consideration for poultry meats over other types of meat globally has led to an interest in the poultry farming and processing industry according to (Wahyono & Utami, 2018) and (Whitnall & Pitts, 2019). With the growing world population, the meat consumption rate will likely increase accordingly to argument the necessary protein requirements of the people (Wahyono & Utami, 2018), it is imperative to develop low cost and simple operational DM to compensate for the population growth. In third world countries, and developing countries like Nigeria, poultry processing has faced challenges of high price, safety, and health concerns according to (Awotunde, Adeyeye, Ponle, & Fatukasi), (Chowdhury & Morey, 2020) and (Omoniyi Ezekiel et al.).

Poultry meat is widely consumed all over the world even among vegetarians because of its richness in protein, low fat, and calorific content (Asante-Addo, Weible, & Pelikan, (Asante-Addo, Weible, & Pelikan, 2020). The likelihood and severity of human exposure to the health hazard and occupational risk as a result of high manual operation are significant in scalding and de-feathering operations (Rupesh Waghamare et al., 2020). This justifies the need for appropriate mechanization of the poultry de-feathering operations to promote economic activities, quality, quantity, safety, and ergonomics. Various machines have also been developed for the de-feathering process which can de-feather poultry birds a large or small scale. There are large numbers of large-scale processing plants currently located in Nigeria but small-sized household capacity is not commonly found (Oniya, Olatunji, Olaniran, & Adejumobi).

To avoid accidents and infections from poultry carcasses that may occur during de-feathering operations, it is

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*Corresponding Author

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imperative to fabricate a user-friendly, efficient and cost-effective de-feathering processing machine (Abubakar, Muhammad, & Salihu, 2018). The fabrication of a de-feathering machine involves designing, planning, modification, and critical analysis of the mechanical properties of the material that would be used (Omoniyi Ezekiel et al.). De-feathering of poultry birds hygienically is essential to avoid food contamination (Pal, Ayele, Patel, & Dulo, 2018). The de-feathering is the process of removing feathers from slaughtered poultry birds. The Manual method of de-feathering poultry birds is tedious, time-consuming, inefficient, expensive, poor quality, and poses health challenges (Sharma, Niwas, Rathore, & Singh, 2020), (Pranav & Patel, 2016) and (Opurong, 2022). This study aimed at investigating the high cost of DM, and seeking to find the right way of addressing the high cost of DM by proving a more viable local alternative material selection.

2 METHODOLOGY

The principal focus of this study was to survey a gamut of variables that affect or impact the operations of the feather plucking machines and the inter-correlation among the variables or scale items. KCC and PCA to study the variables that affect or impact on feather plucking machine process. The research design underpinning this study entails the administration of questionnaires crafted with scale items identified through a wide literature survey and scaled on Rensis Likert's 5-points attitudinal range (Bello, Oyelaran, & Daniyan, 2022). The scale items were administered to twelve (12) selected judges who ranked the twenty-eight variables in descending order of importance. Previous to this, the twenty-eight scale items were referred to the twelve (12) judges who ranked them in the descending order of importance.

The consistency in ranking is represented by KCC and chi-square ($\chi 2$) statistic was used to appraise how consistent the judges were in ranking the scale items. Again, questionnaires were drafted with the 28 scale items and administered to respondents. Respondents' scores were collated as a data matrix and fed into StatistiXL software. The variables were analysed, using KCC, which ranks the variables in merit order sequentially and PCA, which tries to perceive similarity in dissimilarity by achieving parsimony through factor reduction, was embraced. The results such as scree plot, eigenvalue, factor loadings, descriptive statistics, communalities varimax rotated factors loadings, among others, were obtained. These outputs guided the subsequent interpretations that were rendered.

2.1 METHOD OF DATA COLLECTION

An exploratory survey of feather plucking machine variables was done using well-crafted questionnaires. The twenty-eight feather plucking machine variables were used to craft questionnaires scaled with a 5-point Rensis Likert's attitudinal scale and administered to 28 respondents. Respondents' responses were transposed into metric variables.

2.2 THE PRINCIPAL COMPONENT ANALYSIS AND KENDALL'S COEFFICIENT OF CONCORDANCE.

Having transferred the respondent's scores into a data matrix and fed into StatistiXL software, it was successfully used to facilitate the computation of scree plot, eigenvalues and eigenvectors, factor loadings, and descriptive statistics. The mathematical theories that govern the software statistical analysis are shown below in sections 2.2.1 and 2.2.2 respectively.

2.2.1 Kendall Coefficient of Concordance

a. Let N = number of scale items to be ranked and let k = the number of judges assigning ranks.
b. Input the observed rank into the K*N matrix
c. For each entity obtain R_j, which is the total scores of each of the scale item
d. Obtain the mean of the various R_j's, where j refers to the variable response or stimulus from the judges on scale item, i
e. Obtain the deviation of every R_j from the calculated mean of R_j
f. Obtain the square of the deviation of each of the scale items
g. The Kendall Coefficient of Concordance (W), which measures the degree of agreement between the judges is obtained from equation (1)

$$W = \frac{12S}{K^2(N^3-N)} \quad (1)$$

Where $S = \sum(R_j - \sum R_j/N)^2$ = Rank variance (2)

2.2.2 The Abridge Theory of the Application of the Principal Component Analysis (PCA)

Let X_{ij} and Y_{ij} represent a pair of variables in the data matrix. Define column mean as

$$\bar{X}_{.j} = \sum_{i=j}^{N} \frac{X_{ij}}{n_j} \quad (3)$$

and

$$\bar{Y}_{.j} = \sum_{i=j}^{N} \frac{Y_{ij}}{n_j} \quad (4)$$

Then $x = X_{ij} - \bar{X}_{.j}$ and

$y = Y_{ij} - \bar{Y}_{.j}$,

where i and j refer to the state of the matrix, x and y refer to the respective mean deviation or deviation from the mean.

Hence, the Correlation coefficient, r_{ij} is defined as

$$r_{ij} = \frac{\sum xy}{\sqrt{(\sum x^2).(\sum y^2)}} \quad (5)$$

$$x = X_{ij} - \bar{X}_{.j}$$

$$y = Y_{ij} - \bar{Y}_{.j},$$

$$\bar{X}_{.j} = \sum_{i=j}^{N} \frac{X_{ij}}{n_j}$$

$$\bar{Y}_{.j} = \sum_{i=j}^{N} \frac{Y_{ij}}{n_j},$$

When r_{ij} is computed for every pair from the whole lot of ${}^{n}C_2 = \frac{n!}{(n-2)!2!}$. (6)

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3 RESULTS AND DISCUSSION

The twenty-eight scale items were referred to 12 judges who are well-informed on the subject matter to rank them in ascending order of importance. Table 1 depicted the ranking of judges' outcome.

Kendall coefficient of concordance is given by:

$$W = \frac{S}{\frac{1}{12}K^2(N^3 - N)} \quad (7)$$

$$S = \sum\left(R_j - \frac{\sum R_j}{N}\right)^2 \quad (8)$$

R_j = Colum sum of ranks = 24048.2
N = 28
S = Variance
K = Number of Judges = 12
From factor Ranking Matrix
$\sum R_j = 24048.2$

$$\frac{\sum R_j}{N} = \frac{24048.5}{28} = 172.93$$

$$S = \sum\left(Rj - \frac{\sum Rj}{N}\right)^2 = 183899.86$$

Therefore, S= 183899.86

$$W = \frac{183899.86}{\frac{1}{12}13^2(28^3 - 28)} = 0.7$$

Also
$\chi^2 = K (N-1) W = 12 \times (28-1) \times 0.70$
$= 226.8$
(N – 1) = degree of freedom
H_o: The rankings of the 12 judges are discordant
H_1: The judges are using the same standard in ranking
At $\alpha = 0.05$ significant level, $\chi^2 = 79.08$ at 0.1 significant level, $\chi^2 = 74.4$
Since $\chi^2_{cal} = 226.8 > \chi^2_{tab.} = 79.082$, we fail to accept the null hypothesis (H_0) and therefore conclude that the judges ranking of the 28 scale items were consistent.

3.1 PCA DATA PRESENTATION AND ANALYSIS

The PCA is a factor analysis tool. Out of the 120 sets of the questionnaire administered to knowledgeable respondents, 115 were retrieved. This is about night-six percent (96%) success. Respondent's scores were then collated into a data matrix. The respondents' data matrix was fed into StatistiXL software that gave the following output:
i. Scree Plot
ii. Eigen value and Eigen vectors
iii. factor plot (factor loadings)
iv. descriptive statistics result and note information into the text.

3.2 SCREE PLOT

The Figure 1 shows the eigenvalue. It's obvious from the scree plot that at eigenvalue of 1, and component number 11, the scree plot graph tends to flatten out, suggesting that seven factors extracted are adequate.

3.3 FACTOR PLOT

It is clearly indicated in Fig. 2 that the stainless steel variable with variable factor 26 was at the cluster centre. This is indicating the significant role interplay between the stainless steel and other DM variable factors. This is the proof that Stainless Steel is responsible for the high cost of the DM (Rabi, Shamass, & Cashell, 2022). It therefore suggests that replacement of stainless steel with another viable material like hard plastic will drastically reduce the cost DM production (Olorunnisola, 2021). This will promote the sales of the DM as many middle level farmers will be able to afford DM and therefore promote local content and improve the ease doing farming business.

Table 1. Merit Order Sequentially (MOS)

S/No	Ranking Factor	Scale Item
1	50	Operating Cost
2	53	Poultry Birds
3	57	Machine Efficiency
4	63	Defeathering machine cost
5	65	Cost of Production
6	93	Material Selection
7	108	Cold room
8	117	Machine Performance
9	118	Machine Operator
10	120	Capacity
11	130	Finished Product
12	152	Scalding
13	163	Machine Reliability
14	181	Ergonomics
15	183	Pulley
16	188	Hot water
17	190	Availability of Machine
18	194	Lead Time
19	201	Safety
20	229	Feather plucking
21	238	Skin toughness (age, breed, etc)
22	242	Driver Belt
23	250	Plucking force
24	252	Period of Immersion
25	253	Scalding temperature
26	312	Stainless steel
27	316	Electric motor
28	324	Waste Product

weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

3.4 DESCRIPTIVE STATISTICS

The factor variables were withdrawn by statistiXL software, having fed the collated data matrix into it. Factors are extracted at eigenvalues greater than 1.
It's obvious from the scree plot that at eigenvalue of 1, and component number 7, the curve tends to flatten out, suggesting that seven factors extracted are adequate. This shows notable parsimony in factor reduction from 28 to 7.

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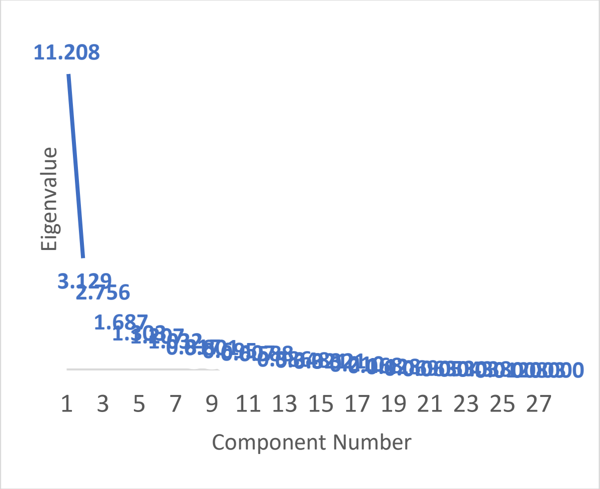

Fig. 1: Scree plot

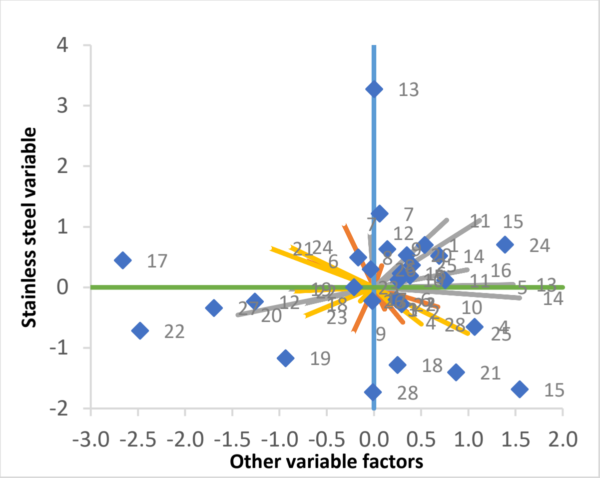

Fig. 2: Factor plot of Stainless-steel variables as most significant

Table 2. Varimax Rotated Factor Loadings of 28 Matrix feather plucking Machine variables

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Operating Cost	0.511	**-0.757**	0.044	0.040	-0.138	0.138	-0.179
Poultry Birds	0.281	**-0.653**	0.135	0.208	-0.157	0.231	0.096
Efficiency of the Machine	0.511	**-0.757**	0.044	0.040	-0.138	0.138	-0.179
Defeathering machine cost	**0.765**	-0.145	0.118	0.010	-0.222	-0.341	-0.237
Cost of Production	0.405	-0.260	0.492	**0.511**	0.005	-0.320	0.094
Material Selection	0.171	-0.351	-0.280	0.033	**0.779**	-0.043	0.187
Cold room	**0.750**	-0.331	-0.124	-0.075	0.405	-0.018	0.223
Machine Performance	**0.640**	-0.260	0.032	-0.030	0.138	-0.069	0.417
Machine Operator	**0.771**	-0.003	-0.086	-0.063	-0.293	-0.036	0.185
Capacity	**0.561**	0.476	0.262	-0.179	-0.125	0.019	0.269
Finished Product	**0.655**	0.266	0.297	0.017	0.429	0.108	-0.207
Scalding	**0.540**	0.340	-0.016	0.382	0.349	0.387	-0.214
Machine Reliability	0.463	0.131	**0.569**	0.444	0.019	0.191	0.351
Ergonomics	0.527	0.251	**0.596**	-0.126	-0.067	-0.199	0.064
Pulley	0.395	-0.032	0.432	-0.156	0.426	**-0.504**	-0.101
Hot water	0.283	-0.234	0.382	-0.148	0.111	0.137	**0.662**
Availability of Machine	0.051	-0.127	-0.045	-0.472	-0.072	**0.764**	-0.042
Lead Time	**0.693**	-0.045	-0.288	-0.432	-0.105	0.028	0.224
Safety	**0.561**	0.211	-0.353	0.382	-0.011	-0.309	0.019
Feather plucking	**0.592**	0.216	-0.557	0.117	-0.176	0.235	-0.095
Skin toughness (age, breed, etc)	**0.600**	0.301	-0.426	0.018	0.250	0.079	0.168
Driver Belt	-0.027	0.170	-0.332	-0.083	-0.127	**0.776**	-0.054
Plucking force	**0.733**	0.162	-0.288	0.047	-0.187	-0.296	-0.082
Period of Immersion	-0.260	-0.070	-0.347	0.126	0.260	-0.399	**0.600**
Scalding temperature	-0.132	0.423	0.383	-0.059	-0.293	-0.178	**0.552**
Stainless steel	-0.088	0.079	-0.055	0.184	**0.847**	0.073	0.030
Electric motor	-0.107	0.319	0.068	0.200	-0.127	**0.693**	-0.183
Waste Product	-0.055	0.271	0.194	-0.171	-0.235	0.369	**0.684**

The highest value on each row was highlighted and formed rationalization for the seven clusters

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Table 3. Cluster 1: Factor 1 (Design specification)

9	Machine Operator	0.771
4	Defeathering machine cost	0.765
7	Cold room	0.750
23	Plucking force	0.733
18	Lead Time	0.693
11	Finished Product	0.655
8	Machine Performance	0.640
21	Skin toughness (age, breed, etc.)	0.600
20	Feather plucking	0.592
19	Safety	0.561
10	Capacity	0.561
12	Scalding	0.540

The bogus principal factor, called design specification, having significant and factor loading ranging from 0.711 to 0.54. The highest factor is Machine operator, this signified the importance of skill knowing how to benefit maximally from the plucking machine performance. Follow by cost and cold room. All these factors are necessary during design consideration.

Table 4. Cluster 2: Factor 2 (Investment Cost)

1	Operating Cost	-0.757
3	Machine Efficiency	-0.757
2	Poultry Birds	-0.653

The cluster consists of three scale items with operating cost as the highest labelled of -0.757. All the scale items are negatives. This suggests that heavy investment in poultry mechanization alone does not guarantee success, all other scale factors need to be well managed to achieve the desired result.

Table 5. Cluster 3: Factor 3 (Factor of safety)

14	Ergonomics	0.596
13	Machine Reliability	0.569

The safety factor in feathering plucking machines is meddling. This indicates that machine reliability and ergonomics are important to maintain a healthy workforce and machine performance

Table 6. Cluster 4: Factor 4 (Running cost)

5	Cost of Production	0.511

The running cost is alone variable with a factor loading of 0.511. Any business success is anchored on the running cost. The cost of running a feather plucking machine is moderate. This is because the part of the machine is few and not complex.

Table 7. Cluster 5: Factor 5 (Cost of Material)

26	Stainless steel	0.847
6	Material Selection	0.779

Stainless still has the highest loading factor of 0.847 as depicted in table 3 and table 8 respectively. The high cost of the de-feathering machine is traceable to the high-cost stainless steel as shown in Table 7. Therefore, to fabricate a low-cost feather machine, there will be a need to replace stainless steel with cheaper materials free of food contamination and equally hygienic.

Table 8. Cluster 6: Factor 6 (Spare parts)

22	Driver Belt	**0.776**
17	Availability of Machine	**0.764**
27	Electric motor	**0.693**
15	Pulley	**-0.504**

Table 8 consists of four factors loading called spare parts. The drive belt has the highest factor loading of 0.776, indicating that inventory of drive belts should be kept since the replacement is not inevitable. Pulley (–ve) factor loading value of -0.504, means that pulley inventory is not necessary as it will not be necessary. Machine availability has a meritorious factor loading of 0.764, this indicates that keeping the necessary spare parts inventory would reduce the downtime and enhance the machine availability.

Table 9. Cluster 7: Factor 7 (Operations Management)

28	Waste Product	0.684
16	Hot water	0.662
27	Period of Immersion	0.600
25	Scalding temperature	0.552

Waste product, hot water temperature, period of poultry product immersion, required scalding temperature are in cluster 7 termed operation management. Effective management of these scale items will enhance the productivity of de-feathering processes. In achieving the research goal, adequate measures were put in place to ensure the accuracy, reliability, and dependability of the results. Accordingly, the research identified twenty-eight scale variables that impact the feather plucking machine operations. The combination of KCC and PCA as statistical tools was utilized to provide insight into the correlation among these variables.

The Kendall's Coefficient of Concordance (w) was 0.7 is considered significant, suggesting there was agreement among the judges that ranked the variables. Consequently, a null hypothesis was rejected at a p-value of 0.05, thus rating the coefficient of concordance (W) = 0.70) is being significant. The significance of the re-ordering of de-feathering variables by the judges is to help the management solve the problems in order of priority. The ranking of the de-feathering scale items implies that management should pay more attention to the issue raised in order of severity. This will offer a veritable framework for achieving productivity in feather plucking machine systems. The questionnaire couched in 5-point Rensis Likert's attitudinal scale helped in extracting the responses from the 65 respondent's score into a data matrix. The PCA tool enable the variables reduction from twenty-eight (28) to seven (7) clusters.

4 CONCLUSION

The study surveyed twenty-eight variable factors that impact the functioning of de-feathering machine processes and established the inter-correlations among the variables. Again, the research enhances the design and fabrication of low-cost high-quality feather plucking machines by replacing the high-cost stainless steel which wielded the highest factors loading of 0.847 for stainless steel, followed by 0.779 for material selection whose replacement with plastic drums enable cost reduction of DM. Furthermore, the research also promotes innovative feather plucking machines; focusing on low-cost, ergonomics, and health and safety of the workforce. The PCA model adopted has reshaped worldview and clarified thinking about the poultry birds processing world. This study has helped to identify variables that influence feather plucking machines and, in addition, provided insight into their merit order and the way the variables interplay relation exists among them. This study has provided an insight for the need to replace stainless steel with viable alternative materials as a way of reducing the DM fabrication cost. This study will serve aa a guide for the stakeholders in poultry business to reduce the cost of investment.

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