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MODIFICATION OF AN EXISTING NSPRI FISH SMOKING KILN

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ABSTRACT

In Nigeria, fish smoking and drying are among the traditional methods of processing and preserving fish for human consumption. Traditional smoking and drying methods available are not efficient. The traditional smoking is usually done in the open where substantial parts of the heat is lost to the environment. One of the remarkable efforts to solve the aforementioned problems is the fish smoking kiln developed by the Nigerian Stored Product Research Institute (NSPRI), Kano. The present study is aimed at modification of the NSPRI smoking kiln for better performance in terms of capacity of the smoking kiln, thermal efficiency and sustainability. The capacity of the smoking kiln was upgraded by increasing the number of trays in the existing kiln. The existing smoking kiln was converted to a double wall and insulation was encased in between the walls to conserve heat for better thermal efficiency. Non-rechargeable batteries were replaced with solar rechargeable batteries to reduce the cost of production for sustainability. The modified smoking kiln was fabricated, and it consists of four major units similar to the existing kiln. These include the fish smoking chamber, heat chamber, oil collection and heat circulation units. Performance evaluation of the modified smoking kiln was carried out using a completely randomized design (CRD) in a $3 \times 3 \times 3$ *factorial experiment. The smoking kiln was evaluated using output capacity, smoking rate, moisture removal rate and fuel consumption rate as performance indicators and tray position, fuel source, and fan speed as independent variables. The results of the modified smoking kiln were compared with the existing smoking kiln. The results revealed that the highest output capacity, smoking rate and moisture removal rate for the modified smoking kiln were 65.76 kg/h, 49.80 kg/h and 19.22 %/h respectively. Comparison showed that there is significant difference in the results of the two smoking kilns at 1% probability level. The modified kiln has 50 % increase in the batch capacity, 186 % increase in the output capacity and 220 % increase in the moisture removal rate as compared with the existing kiln.*

Keywords: Fish processing; NSPRI/traditional smoking kilns; Modification; Fabrication; Evaluation.

1. INTRODUCTION

Fish is a highly nutritious food containing about 50-55% water, 12-19% protein, 10-15% fat, 10% mineral and 1% carbohydrate (Adams and Moss, 1999). It is often cheaper than meat and so it is a rich protein source for various people from different socio-economic strata. On the downside, fish is a highly perishable food commodity as it provides suitable media for the growth and proliferation of microorganisms that cause it spoilage. Uzukegbu and Eke (2000) estimated postharvest loss of fishes in Nigeria arising from bacterial and autolytic spoilage to be up to 20%. Similarly, FAO (2001) estimated post-harvest losses of about 25% of the total world catch annually. Hence, the preservation of fresh fish against spoilage becomes very important. Because the storage of fresh fish without preservative or poor processing measures makes it to be highly susceptible to deterioration.

Fish preservation is achieved using different methods. Some of these methods include cooking, frying, salting, freezing, canning, dehydration through smoking and drying. Currently, fish smoking is a common method of fish preservation in rural areas of Nigeria. According to FAO (2007), smoking is one of the preservative methods employed by traditional fishermen to preserve fish using traditional kilns of various types depending on the locality. Smoking is done to reduce the moisture content of the fish to a level that prevents deterioration it also gives the fish a mesmerizing aroma. It has been observed that fish smoking practices are yet to gain prominence on a large commercial scale in Nigeria due to the lack of appropriate technologies to assist the fish farming business (Ashaolu, 2014).

The demand for fish is on the increase both in local and global markets. Large scale processing of fish is necessary to satisfy the increasing demand for the products. Thus, the development of a more efficient smoking kiln would contribute immensely to fish processing activities. Several efforts have been made to develop fish smoking kiln locally in response to the yawning of the fish producers in the country. One of the remarkable efforts to address this problem is the fish smoking kiln developed by the Nigerian Stored Product Research Institute (NSPRI), Kano. Figure 1 presents the existing NSPRI fish smoking kiln. The fish smoker is a single wall kiln with the length, width and height of 1230, 600 and 1217 mm respectively. It has a capacity of 100 kg of fish per batch and it was evaluated to have moisture removal rate and output capacity of 6%/h and 25 kg/h respectively (Kamaldeen *et al*., 2016). Based on the report of Kamaldeen *et al*. (2016), and physical assessment of the kiln, a modified smoking kiln of equal size and similar configuration that will address the limitations; small batch capacity, low output and moisture removal rate in the existing kiln for a better performance in terms of capacity, thermal efficiency and sustainability was conceived. The present study therefore intended to re-design, construct and evaluate the performance of the modified NSPRI fish smoking kiln.

Figure 1: Rear and front views of the existing NSPRI smoking kiln (Kamaldeen *et al*., 2016)

2. MATERIALS AND METHOD

2.1 Re-design Considerations

In the modified smoking kiln, the following design considerations were made:

i. Improved output capacity to serve the needs of medium-scale processors.
ii. Heat retention to improve the thermal efficiency of the smoking kiln.
iii. Sustainability of the kiln.
iv. Use of locally available materials.

2.2 Modified Components of the existing Smoking Kiln

Though the configurations of the existing smoking were maintained in the modified smoking kiln, but the following components were amended for better performance of the newly fabricated modified smoking kiln.

i. The capacity of the smoking kiln was upgraded by increasing the number of trays from 4 to 6 (100 to 150 kg capacity per batch).
ii. The smoking kiln was converted to double wall and thermal insulator (polyurethane foam) was encased in between the walls to conserve heat for higher thermal efficiency.
iii. Non-rechargeable batteries were replaced with solar rechargeable batteries to reduce the long-term cost of production for the sustainability of the kiln.
iv. Roller wheels were fixed for easy transportation of the smoking kiln.

2.3 Re-design Parameters and Analyses

The re-design calculations were based on the following specifications and assumptions: Minimum ambient temperature (T_1) of 21ºC and maximum average relative humidity (Rh) of 96 % of Kano State weather conditions (NIMET, 2016). The drying temperature in the smoking kiln chamber (T_2) was taken as 85 ºC (Akande and Adeyemi, 2016). Six trays with dimensions of 0.58 m by 0.58 m (from the existing smoking kiln). The specific heat capacity of catfish is 3.63 kJ kg^{-1}.ºC (Adeyemi and Akande, 2011). Moisture content of fresh fish is 75 %, (m.c) wb (Umar, 2016). Dried moisture content of 15% based on the safe storage moisture content of fish reported by Oparaku and Mgbenka, (2012).

i. Batch capacity (kg)

The batch capacity of the modified kiln was estimated as follows:
From the existing smoking kiln,
Tray of length, width and depth of 0.9 m × 0.9 m × 0.045 m contains 25 kg of cat fish (Kamaldeen *et al*., 2016).
Therefore, the batch capacity (M) of the modified smoking kiln having six trays will:

$M = 25\,kg \times 6$

$M = 150$ kg/ batch

ii. Amount of moisture to be removed in kg (M_R):

In fish smoking, the fish is smoked-dried. Hence, the amount of moisture to be removed was calculated as given by Ichsani and Dyah (2002):

$$M_R = M \times \left(\frac{Q_1 - Q_2}{1 - Q_2}\right) \qquad (1)$$

Where,
M = smoking capacity per batch (150 kg)
Q_1 = Initial moisture content of the fish to be dried
Q_1 is 75% wb Umar (2016)
Q_2 = Desired final moisture content
Q_2 is 15% Based on the safe storage moisture content of fish. (Oparaku and Mgbenka, 2012)

$$M_R = 150 \times \left(\frac{0.75 - 0.15}{1 - 0.15}\right)$$

Therefore the amount of moisture to be removed = 105.88 kg.

iii. Drying rate (D_r)

The smoking rate was determined using the expression by Donald (1974) give as:

$$D_r = \frac{M_R}{t} \qquad (2)$$

Where,

t = time taken to smoke the fish (assume 4 hours)

Therefore,

$$D_r = \frac{105.88}{4}$$

$$D_r = 26.47\ kg/h$$

iv. Mass of air required for drying in kg/h (Ma).

This was calculated as (Akande and Adeyemi, 2016):

$$M_a = \frac{D_r}{H_{r2} - H_{r1}} \qquad (3)$$

Where,

H_{r1} and H_{r2} = initial and final humidity ratio in kg/kg dry air, respectively

Using the ambient temperature (T_1) of 21ºC, average relative humidity (Rh) of 96 % and drying temperature in the smoking kiln chamber (T_2) of 85 ºC. The initial humidity ratio H_{r1} is determined to be 0.0150 kg/kg dry air using the online psychometric calculator under normal temperature and 1.01325 bar barometric pressure (Sugartech, 2020). When the heat is supplied, the temperature of the air rises to 85 ºC giving the final humidity ratio H_{r2} as 0.2151 kg/kg dry air.

$$M_a = \frac{26.47}{0.2151 - 0.0150}$$

$$M_a = 132.28\ kg/h$$

v. The volumetric flow rate of the drying air (m^3/s)

The volume of drying per unit time required was calculated as given by Akande and Adeyemi (2016):

$$m_v = M_a \times V_s \qquad (4)$$

Where,

m_v = volumetric flow rate of the drying air in (m^3/s)

M_a = mass of air required for effective drying = 132.28 kg/h (from Eqn 3)

V_s = specific volume of the drying air = 1.3618 (m^3kg^{-1}) Psychrometric chart

$$m_v = 132.28 \times 1.3618$$

$$m_v = 180.14\ m^3/h \quad \text{or} \quad m_v = 0.05\ m^3/s$$

Therefore, when converted to Cubic feet per minute (CFM) using the conversion factor 1CFM=1.6990m³/h

$$m_v = 180.14\ m^3/h = 106.03\ CFM$$

vi. Design and selection of size and type of fan to convey the drying air

The blower serves the purpose of transferring heated air from the heat chamber to the dryer chamber. The power required to drive the blower was determined according to Henderson and Perry (1997) as simplified by Eckelman and Baker (1976) in Equation (5):

$$H_P = \frac{P_W \times m_v}{6356 \times e} \qquad (5)$$

Where;

H_p = Motor horsepower

P_w = pressure in inches of water, 18 (But, 2009)

e = fan efficiency, (45%) Ehiem *et al.*, (2009)

m_v = volumetric flow rate of the drying air from Eqn 4

$$H_P = \frac{18 \times 180.14}{6356 \times 45}$$

$$H_P = 0.0113$$

But

1 horsepower hp = 745.70 watts W (Denholm and Margolis, 2006).

Therefore,

$$H_P = 0.0113\ hp\ \text{or}\ (8.43\ watts)$$

vii. The heat required for smoking (Hr) in kJ

This is given by Ehiem *et al.* (2009) as:

$$H_r = (M \times H_K) + (H_L \times M_R) \qquad (6)$$

Where,

H_r = Heat required for smoking kJ

M = Smoking kiln capacity per batch (60 kg)

$$H_K = CT(T_2 - T_1) \qquad (7)$$

Whereas,

CT = Specific heat of fish 3.5 kJ/kg

T_1 = ambient temperature

T_2 = temperature in the smoking kiln chamber

$T_2 - T_1 = 85 - 21 = 64$ °C

H_L = Latent heat of vaporization of fish = 1200 kJ/kg (Donald, 1974)

M_R = Amount of moisture to be removed (42.353 kg)

$$H_r = (M \times H_K) + (H_L \times M_R)$$

$$H_r = (150 \times 224) + (1200 \times 42.353)$$

$$H_r = (33600 + 50823.6)$$

$$H_r = 84423.6\ kJ$$

viii. Thermal resistance due to insulation R_{value} (K/W)

Rigid polyurethane foam 0.03 m thickness with thermal conductivity of 0.02 W/mK and packing density of 80 kg m⁻³ was encased in between two metal sheets of 45 W/mK thermal conductivity and thickness of 0.002 m. Considering the thermal resistance before insulation R1 and thermal resistance after linsulation R2 for the unit area of the combustion chamber as given by Holman (2002):

$$R1 = \frac{\Delta x1}{k1} \qquad (8)$$

$$R1 = \frac{0.002}{45} = 4.44 \times 10^{-5}\ K/W$$

$$R2 = \left(2 \times \frac{\Delta x1}{k1} + \frac{\Delta x2}{k2}\right) \qquad (9)$$

$$R2 = \left(2 \times \frac{0.002}{45} + \frac{0.03}{0.02}\right) = 1.50\ K/W$$

Where,

$\Delta x1$ = thickness of mild sheet 0.002 m

$\Delta x2$ = thickness of polyurethane foam 0.03m

k1 = thermal Conductivity of mild steel = 45 W/mK

k2 = thermal Conductivity of polyurethane foam = 0.02 W/mK

2.4 Material Selection, Fabrication and Cost Estimate

The material selected for the modified smoking kiln components was based on the functions they are expected to serve, the environmental condition in which they will work, their useful physical and mechanical properties, cost and their availability in the market. The bill of materials for the smoking kiln as at the year 2017 was estimated as ₦ 105, 282. The breakdown of the bill of materials is outlined in Table 1:

Table 1: Bill of materials for the kiln

Material	**Quantity**	**Unit price (₦)**	**Total (₦)**
Mild Steel Sheets	5	6000	30000
Rigid polyurethane foam	2	5000	10000
Wire Mesh (2.5m x2.5m)	3	5000	15000
Steel angle bar (45x45x2mm)	2	3000	6000
Bolt and Nuts M10x3	50	12	600
Fans	2	2000	4000
Solar Panel (80W)	1	20000	20000
Battery (12V DC battery)	1	14000	14000
Charge regulator (2 Amp)	1	8500	8500
Fans speed regulator	2	500	1000
Paint (Finishing: Paints)	1 gallon	2500	2500
Bearings	4	100	400
Hinges (90mm size)	5	100	500
Galvanized Sheet Iron (Thickness 1mm)	3	3000	9000
10% Contingency			13,782
TOTAL			105,282

2.5 Description of the Modified Smoking Kiln

The assembly drawings and the parts list of the modified fish smoking kiln is presented in Figure 2. The kiln is double-walled with polyurethane foam encased as insulation material between the inner and outer walls. The frame was constructed from angle iron, 45 x 45 mm. The materials of construction for the entire body are made of 1 mm galvanized iron sheets for the inner and outer walls. The base is made of mild steel, 2 mm thick. The smoking kiln comprises different units, these include the smoking chamber, heat chamber, heat circulation unit, and oil collection unit. Other important parts include the fan, the solar panel and battery. The smoking chamber is $1 \times 0.60 \times 1$ m in dimension. Galvanized steel wall was selected for its strength, heat transfer properties and cost. The fish trays were made from galvanized wire mesh. The tray has a length of 0.58 m, and a width of 0.58 m. Oil collection unit consists of an open tray placed below the fish trays and it is used to collect dropping oil from the smoked fish. The oil collection tray is made of galvanized sheet, 1.2 mm thick. The combustion chamber is placed under the smoking chamber; the hot air from the combustion chamber is conveyed to the smoking chamber by the combustion chamber's fan centrally positioned at the back and facing the smoking chamber and the smoking chamber's fan distributes the hot air within the smoking chamber. The two fans are powered by a solar PV cell. The chimney was provided to enhance the extraction of humid air/smoke mixture from the smoking chamber. It also conveys the exhaust air high above to reduce the inhalation of smoke by the operator.

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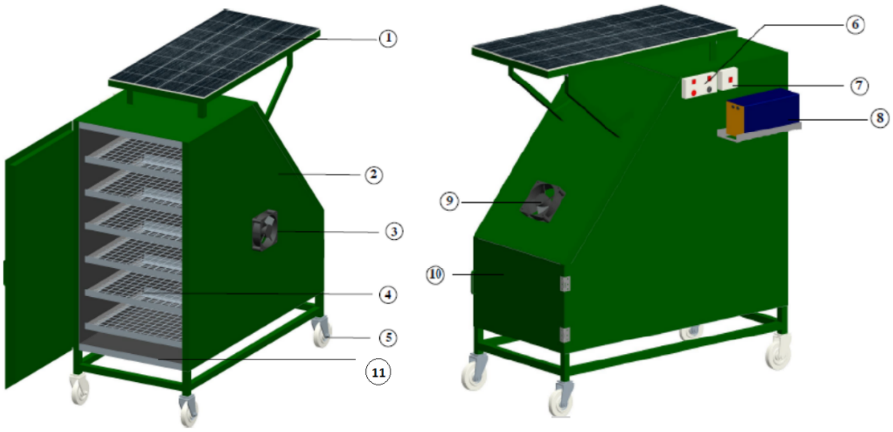

Label Number	Name of Parts
1	Solar panel
2	Smoking chamber
3	Smoking chamber's fan
4	Tray
5	Roller wheel
6	Switch
7	Fan regulators
8	Battery
9	Heat chamber's fan
10	Heat chamber
11	Oil collection tray

Figure 2: Assembly drawings and parts list of the modified fish smoking kiln

2.6 Performance Evaluation of the Smoking Kiln

Performance evaluation of the modified smoking kiln was carried out using catfish (*Clarias gariepinus*). Figure 3 presents side view of the modified smoking while Figure 4 present the modified smoking kiln during experiment. Experiments were done in three (3) replications, observations were made while operating the smoking kiln and relevant data were collected. The following performance indicators were computed using the method reported by Adamu *et al*. (2013)

i.) Output capacity O_c (kg/h)

$$O_c = \frac{\text{Weight fish before smoking}}{\text{Time of smoking}} \qquad (10)$$

ii.) Fish smoking rate S_r (kg/h)

$$S_r = \frac{\text{Weight of the smoked fish}}{\text{Time of smoking}} \qquad (11)$$

iii.) Moisture removal rate M_{rr} (%/h)

$$M_{rr} = \frac{\text{Initial mc} - \text{Final mc}}{\text{Time taken}} \qquad (12)$$

iv.) Fuel consumption rate F_c (kg/h)

$$F_c = \frac{\text{Quantity of fuel consumed}}{\text{Smoking time}} \qquad (13)$$

2.7 Experimental Design and Layout

The experiment was conducted using 3 × 3 × 3 factorial experiment in a completely randomized design (CRD). Three (3) different fuels (F1, F2 and F3 of charcoal, sawdust and rice husk, respectively), three (3) tray positions (T1, T2 and T3 of the Upper, Middle and Lower tray, respectively) and three (3) level of fan speeds (S1, S2 and S3 of 400, 600 and 800 rpm, respectively). The combination of these factors gave 27 treatments. Each of these treatments was done in three (3) replications making the number of experiments conducted to be eighty-one (81). The smoking process was terminated in each case when equilibrium moisture content (EMC) of the smoked fish samples was achieved. The total time spent on each experiment and weight of fish obtained were measured and recorded accordingly. The data recorded were used in the computations of the performance parameters (Smoking rate, moisture removal rate and fuel consumption rate). The data obtained from the performance evaluation were subjected to analyses of variance using the SAS package. Further analyses were done to compare treatment means that were statistically significant using the least significant difference (LSD).

Figure 3: Side view of the modified smoking kiln

Figure 4: Modified smoking kiln during performance evaluation

3. RESULTS AND DISCUSSION

3.1 Moisture Removal Rate

The analysis of variance results for moisture removal rate is as shown in Table 2. The results show that heat source, fan speed and their interactions are significant on moisture removal rate at 1% probability level. The effect of the tray position was not significant on the moisture removal rate. This implies that there is even distribution of heat inside the smoking kiln. These trends agree with results reported by Rahman, (2006) and Mujumdar, (2006) for fish dryers.

Table 2: Analysis of variance for moisture removal rate

Sources of variation	Degree of freedom	Sum of Square	Mean Square	Calculate F	Pr > F
Replication	2	1339.1559	669.5779	9.82	0.0002
Heat Source (C)	2	14011.9139	7005.9570	102.77**	<0.0001
Speed (S)	2	1134.0261	567.0130	8.32**	0.0007
Tray (T)	2	210.7741	105.3871	1.55 ^{NS}	0.2227
C*S	4	1080.8608	270.2152	3.96**	0.0070
C*T	4	331.6194	82.9048	1.22 ^{NS}	0.3152
S*T	4	70.7091	17.6773	0.26 ^{NS}	0.9027
C*S*T	8	507.5777	63.4472	0.93 ^{NS}	0.4994
Error	52	3544.8575	68.1703		
Total	80	22231.4945			

Note: NS = Not Significant, ** = Significant at 1% Probability level

Table 3 presents the results of the further analysis using LSD for factors that are significant on the moisture removal rate. The results show that moisture removal rate increase with an increase in fan speed. This agrees with Rahman (2006) and Mujumdar (2006).

Table 3: LSD for moisture removal rate

Treatments	Moisture removal percentage (%/h)	LSD
Charcoal (C1)	19.22	A
Sawdust (C2)	10.97	B
Rice husk (C3)	10.73	B
800 rpm (S3)	14.53	A
600 rpm (S2)	14.33	A
400 rpm (S1)	12.05	B

Note: Means with the same letters are not significantly different

Moisture removal rate was highest (14.53 %/h) at 800 rpm, and the least moisture removal rate of 12.05 %/h was observed at the speed of 400 rpm. The results for the heat source show that sawdust and rice husk are statistically at par and lower than Charcoal. The best combination of variables that give the highest moisture removal rate of 19.22 % is at a speed of 800 rpm using charcoal as sources of heat.

3.2 Smoking Rate The analysis of variance for smoking rate results is shown in Table 4. The results show that the heat source is significant on the smoking rate at 1 % probability level. This agrees with the findings of Rahman, (2006) and Mujumdar, (2006) for fish dryers. The fan speed and the tray position were not significant. All the interactions were also not significant.

Table 4: Analysis of variance for smoking rate

Sources of variation	Degree of freedom	Sum of Square	Mean Square	Calculate F	Pr > F
Replication	2	2650.1282	1325.0641	9.57	0.0003
Heat Source (C)	2	9411.6761	4705.8381	34.00**	<.0001
Speed (S)	2	245.2644	122.6321	0.89 ^{NS}	0.4185
Tray (T)	2	341.6884	170.8442	1.23 ^{NS}	0.2994
C*S	4	799.2899	199.8225	1.44 ^{NS}	0.2329
C*T	4	549.6248	137.4062	0.99 ^{NS}	0.4199
S*T	4	208.7223	52.1806	0.38 ^{NS}	0.8240
C*S*T	8	2029.8553	253.7319	1.83 ^{NS}	0.0917
Error	52	7197.8529	138.4203		
Total	80	23434.1022			

Note: NS = Not Significant, * = Significant at 5% Probability level, ** = Significant at 1% Probability level

The LSD results for the heat source (Table 5) show that the mean values of the smoking rate for charcoal and sawdust are statistically at par and higher than those for rice husk.

Table 5: LSD for smoking rate (SR)

Treatments	Smoking Rate (kg/h)	LSD
Charcoal (C1)	49.80	A
Saw dust (C2)	47.80	A
Rice husk (C3)	29.44	B

Note: Means with the same letters are not significantly different

The best combination which gives the highest smoking rate (49.80 kg/h) is the one using either charcoal or sawdust at a speed of 800 rpm.

3.3 Output Capacity of the Modified Smoking Kiln using different Heat Sources.

Table 6 presents the ANOVA for the output capacity. Results show that heat source and the interaction of heat source, speed and tray positions are significant at 1 % probability level. While the speed and the interaction of heat source and speed are significant at 5 % probability level. This trend is similar to the findings of Umar, (2016) and Rahman (2006).

Table 6: Analysis of variance for output capacity (kg/h)

Sources of variation	Degree of freedom	Sum of Square	Mean Square	Calculate F	Pr > F
Replication	2	1036.0502	518.0251	5.91	0.0049
Heat Source (C)	2	912.5476	456.2738	5.21**	0.0087
Speed (S)	2	814.5296	407.2648	4.65*	0.0139
Tray (T)	2	80.6010	40.3005	0.46 ^{NS}	0.6340
C*S	4	908.5514	227.1379	2.59 *	0.0472
C*T	4	415.1439	103.7860	1.18 ^{NS}	0.3288
S*T	4	162.1067	40.5267	0.46 ^{NS}	0.7630
C*S*T	8	2549.1465	318.6433	3.64**	0.0020
Error	52	4558.2139	87.6580		
Total	80	11436.8908			

Note: NS = Not Significant, * = Significant at 5% Probability level, ** = Significant at 1% Probability level

Further analysis using LSD is presented in Table 7. The result shows that the mean output capacity for sawdust and rice husk heat sources are statistically at par but lower than the mean output capacity for charcoal (C_1). The mean output capacity values for speeds 600 rpm (S_2) and 400 rpm (S_1) are statistically at par but lower than mean values for S_3 (800 rpm). The best combination which gives the highest mean values of output capacity (65.76 kg/h) is the one with a speed (S_3) of 800 rpm using charcoal as heat source at tray position T_1.

Table 7: LSD for output capacity

Treatments	Output Capacity (kg/h)	LSD
Charcoal (C1)	65.76	A
Saw dust (C2)	61.65	B
Rice husk (C3)	60.21	B
400 rpm (S1)	65.39	A
600 rpm (S2)	62.25	B
800 rpm (S3)	59.98	B

Note: Means with the same letters are not significantly different.

3.4 Fuel Consumption rate

The results of the fuel consumption of the smoking kiln using three different heat sources are presented in Table 8 The results show that the mean values of fuel consumption for the smoking kiln were 2.01, 3.14 and 4.06 kg/h for charcoal, sawdust and rice husk respectively. This implies that the smoking kiln consumes more rice husk followed by sawdust and the least in fuel consumption is charcoal. This trend may be due to the differences in density and calorific values of the heat sources.

Table 8: Fuel consumption of the developed fish smoking kiln with different heat sources

S/N	Fuel consumption rate (kg/h)		
	Charcoal	Sawdust	Rice husk
1	2.00	3.11	4.20
2	1.75	3.50	3.80
3	2.33	2.80	4.20
Mean	2.01	3.14	4.06

3.5 Comparison of the modified and existing NSPRI smoking kilns

Table 9 presents the mean values and the t-test results for the various performance parameters of the modified and the existing smoking kilns. In the table, the results of the modified kiln using charcoal as fuel is compared with results of the existing kiln using charcoal as it was reported by Kamaldeen *et al.*, (2016). The results showed that the batch capacity is increased from 100 kg in existing kiln to 150 kg in the modified kiln. This infers 50 % increase in the batch capacity of the kiln. The output capacity is increased from 23 kg/h in existing kiln to 65.76 kg in the modified kiln. It implies 186 % increase in the output capacity of the kiln. The moisture removal rate was 6 %/h in existing kiln, it is increased to 19.22 %/h in the modified kiln. This implies 220 % increase in the moisture removal rate of the kiln. The t-test results showed that the increaments in the batch capacity, output capacity and the moisture removal rate are significant at 1% probability level.

Table 9: Mean values and t-test for the performance parameters of modified and existing smoking kilns

Parameters	Mean values		t-Calculated	t-Critical
	Modified kiln	Existing kiln		
Batch capacity (kg)	150	100	28.87**	9.32
Output capacity (kg/h)	65.76	23	27.35**	11.61
Moisture removal rate %/h	19.22	6	38.61**	14.17
Fuel consumption rate (kg/h)	2.01	NA		
Smoking Rate (kg/h)	49.80	NA		

** Significant at 1% probability level NA Not available

3.6 Conclusions

The following conclusions were made:

1. A modified fish smoking kiln to address the shortcoming in the existing kiln was re-designed, fabricated and evaluated.
2. In the modified smoking kiln, the highest output capacity and moisture removal rate of 65.76 kg/h and 19.22 %/h were achieved at the fan speed of 800 rpm using charcoal as the heat source.
3. There is 50 % increase in the batch capacity of the smoking kiln and the performance evaluation of the modified kiln revealed 186 % increase in the output capacity and 220 % increase in the moisture removal rate when compared with the existing smoking kiln.

3.7 Recommendations

The following recommendations were therefore made:

1. The modified smoking kiln should be tested using other species of fish aside the catfish used in this study.
2. Additional fan speed levels should be experimented to determined the optimum fan speed for the modified kiln.

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