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EFFECT OF EQUIPMENT MAINTENANCE ON THE PERFORMANCE EVALUATION OF FOOD AND BEVERAGE MANUFACTURING INDUSTRIES IN NIGERIA.

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Abstract
The performance evaluation of equipment maintenance practices in manufacturing industries (Nigerian bottling company (NBC) Benin Plant and BONS Industries Ltd, Enugu Nigeria) was carried out. This was a retrospective study. Records on maintenance of filler machine, Packer/Caser, Blow Mould machine, Monobloc (filler/Capper/Rinser) machines were collected for a period of five years from 2017-2021 using a questionnaire. This questionnaire was designed to capture the cumulative end of the year production and maintenance parameters for the industries which includes: year of manufacture of equipment, year of installation, types of maintenance done on the machine, total hours of failure for the year, year product target, year actual volume of product produced and the quantity of defective product. The machines for NBC were obtained and installed in 2008, and the ones from BONS Industries were obtained and installed in 2014. The world class OEE (Overall Equipment Effectiveness) mathematical model was used to evaluate the maintenance performance. For NBC, the availability rate of filler machine ranged from 93.0% - 96.9%, Performance rate ranged from 66.2% - 129.3% while the quality rate was 99.9% for all the years. For BONS water line, the availability rate of monobloc machine ranged from 86.8%-95.8%, the performance rate ranges from 47.2%-96.1% while the quality rate ranges from 91.8%-93.7%. The approaches used for the maintenance of the machines in NBC were preventive and usage based approaches while the maintenance approaches used in BONS bottled water line were preventive and condition based. The availability rate, performance rate and quality rate were high however performance rate was lower in the year 2020 for both industries. However, all the rates in NBC were better than those of BONS Industries Ltd.

1.1 **Introduction**

"The combination of all technical, administrative, and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function" is the definition of maintenance given by the European standard (Alsyouf, 2004). It results in low-defect, high-quality goods, a secure and safe

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work environment, faster production, and an overall improvement in the plant's efficiency. Nigeria is a large developing nation with numerous economic difficulties. Since 2016, it has had more than two recessions. Some businesses have folded as a result of this. For a variety of reasons, some that are still operational do not operate at their best. But the fierce rivalry among businesses and the booming population of Nigeria necessitate that the remaining businesses operate at their highest level (Mifdal et al., 2013). The machines require maintenance in order to operate at their best. On the other hand, maintenance ought to be seen as a profit center rather than as avoidable costs, as some people believe it to be a waste of resources (Al-Najjar et al., 2001; Al-Najjar and Alsyouf, 2004).

Long-term financial gain is the outcome of effective maintenance, which also affects production and its operational elements, including capacity, quality, costs, the environment, and safety (Al-Najjar, 2002). Compared to the simple machinery utilized prior to World War II, the machines employed in industrial organizations nowadays are automated (Alsyouf, 2007). In today's machines, quality, safety, environment, multiskilling, availability, and maintainability (RAM) are all regarded as critical components. Globalization makes it possible to establish local and international connections for equipment maintenance. Various maintenance approaches are available, such as proactive, predictive, holistic, and reactive methods.

1.2 Statement of the Problem

It is well recognized that low productivity, low profit, and decreased machine efficiency and reliability are all caused by improper maintenance of machinery and equipment. Application of appropriate maintenance techniques will lead to higher productivity, significant profit margins, and industrial sustainability. Examining the maintenance culture and strategy of companies in emerging nations with limited resources, such as Nigeria, is crucial.

1.3 Objective of the study

The main objective of the study is to examine the effect of Equipment Maintenance on the Performance Evaluation of Food and Beverage Manufacturing Industries in Nigeria. The specific objectives are to;

i. Examine Conduct quantitative survey of maintenance approaches in the performance evaluation of Food and Beverage Manufacturing Industries in Nigeria.
ii. Determined effect of quality maintenance on the performance evaluation of Food and Beverage Manufacturing Industries in Nigeria.

1.4 Hypotheses of the study

i. Conduct quantitative survey of maintenance approaches has no significant effect in the performance evaluation of Food and Beverage Manufacturing Industries in Nigeria.
ii. Quality maintenance has significant effect on the performance evaluation of Food and Beverage Manufacturing Industries in Nigeria.

2 Review of Related Literature

2.1 Equipment Maintenance and Evaluation

Maintenance is defined according to the European standard (Alsyouf, 2004) as “the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function”. It leads to high quality and low defect products, safe and secured work environment, increased production speed and the overall improvement of the performance of the plant.

Evaluation: This is an act of ascertaining of fixing the value of worth of an equipment in this concept. It is an appraisal of the value/effectiveness of the machines.

2.2 Types of maintenance approaches

- Reactive Maintenance: The moment machine breaks down, it will be immediately fixed.
- Preventive Maintenance: There will be a parts replacement schedule ahead of time before parts breakdown, usually at a regular interval.
- Usage-Based Maintenance: The parts are replaced when the machine has been used for certain period of time before they breakdown.
- Condition-Based Maintenance: The parts are replaced when they seem to getting too worn out to continue functioning appropriately.
- Predictive Maintenance: The historical data are utilized to make predictions about when a part will break and replace the parts based on these predictions, prior to them breaking. This usually, but not always, utilizes artificial intelligence and machine learning.
- Prescriptive Maintenance: This involves using advance data analysis methods to do more than predict failure points, but instead provides hypothetical outcomes in order to choose the best action that can be taken prior to failure, safety hazards, and quality issues arise as well as the timing of implementation.

Using the right maintenance approach for manufacturing equipment gives room for a better machine performance. However, we will go further to elaborate on the strategies/types of maintenance that are mostly used in manufacturing industries.

2.2.1 Reactive approach

Before the World War II, this approach was used. No action is taken to prevent failures or to detect the onset of failure. Machines were simple and are usually replaced when they break down. The maintenance related costs are usually high, but this approach could be considered cost-effective in certain cases (Al-Najjar, 1997; Kelly, 1997; Pintelon and Gelders, 1992)

Reactive maintenance is the starting point for most manufacturers. It's the traditional method of maintenance that has been with manufacturing as long as manufacturing has existed.

2.2.2 Preventive maintenance approach

After the World War II, Preventive maintenance was practiced. It is formally defined as ‘‘the maintenance carried out at predetermined intervals or corresponding to prescribed criteria and intended to reduce the probability of failure or performance degradation of an item’’ (British Standard, 1984). These pre- determined intervals can be either time-based (calendar time) or usage-based, total operating time, number of operations, mileage (Waeyenbergh and Pintelon, 2002; Kumar, 1996). These intervals are determined using statistical-based models and optimization, which is the case when implementing preventive maintenance (PM) policies such as age and block replacements (Sherwin, 2000).

Once manufacturers see that reactive maintenance isn't working, the next logical step is calendar-based maintenance, also known as time-based maintenance (TBM) or preventive maintenance.

This is a form of planned maintenance that is scheduled ahead of time in order to replace parts before they break down. This is done at a set interval such as every 30, 60, or 90 days. In this way, manufacturers can expect a certain amount of downtime or schedule maintenance during off hours. This helps ensure that equipment will be up and running during all planned production periods barring emergencies or unforeseeable circumstances. Calendar-based maintenance uses the concept of “Mean Time Between Failure” (MTBF) to determine the best interval at which to replace parts based on when they have failed in the past. It works best for parts that encounter regular use and predictable wear-and-tear.

Preventive maintenance can work well for machinery that is used on a regular schedule, that has affordable parts that can be easily replaced, has a predictable wear-and-tear rate. It's simple, predictable, and effective in these cases. Preventive maintenance can be beneficial when paired with other maintenance strategies such as predictive or prescriptive maintenance.

2.2.3 Predictive approach:

This approach was used in the 1970s and it is concerned mainly with detecting hidden and potential failures and predicting the condition of the equipment.

Predictive maintenance outperforms our prior-discussed options by blending many of the benefits of each category. This system helps manufacturers predict when maintenance is most likely to be needed, and it does so with increasing accuracy.

Predictive maintenance utilizes technology such as artificial intelligence, machine learning, and IoT devices in order to predict when failures will occur so manufacturers can plan for them in advance and replace parts before consequences arise. The goal of predictive maintenance is to hit the Goldilocks zone of maintenance frequency not too often and not too rarely. This avoids pitfalls in over-maintenance such as excessive parts and labor costs, waste, and increased risk of human error. It also prevents issues associated with under-maintenance such as critical failure, unplanned downtime, and damage to machinery or employees.

In order to do this, data is collected from factory machines equipped with IoT sensors which is then analyzed based on both current and historical data, often utilizing machine learning, to find trends and predict failure.

2.2.4 Holistic (process oriented) approach

Here, monitoring the deviations in machine condition and product quality are done (Al-Najjar, 1997). Local and foreign partnership can be created to enhance maintenance. Terotechnology, TPM, RCM have been proposed also (Sherwin, 2000; Waeyenbergh and Pintelon, 2002).

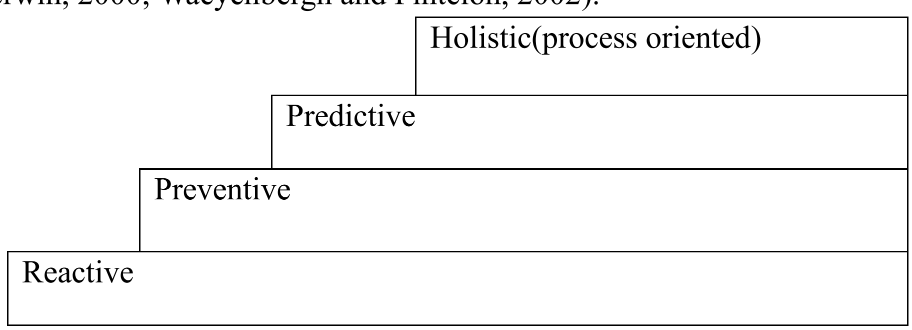

Fig 1: Development of maintenance approaches
Source: Alsyouf, 2007

Condition-Based Maintenance

Condition-Based Maintenance takes some of the guesswork out of predicting maintenance schedules using the calendar- and condition-based maintenance methods mentioned previously.

This form of maintenance is similar to usage-based maintenance, but with much more frequent monitoring and a greater volume and depth of data. Is the tool showing signs of wear? Is performance decreasing or is it showing other signs of impending failure? Maintenance only occurs when the quality of an item dips below a certain predetermined threshold. Measurements may occur continuously using sensors connected to the tool or machine, or it may come from less frequent analog methods of data collection such as visual inspection.

Condition-based maintenance is a step up from usage-based, calendar-based, and reactive maintenance when it comes to the cost of parts. Because condition-based maintenance only replaces parts when they are expected to fail soon manufacturers get more usage for their money without the damage and downtime that comes from pushing parts to the point of failure as occurs with a reactive maintenance strategy.

There are additional costs associated with frequent monitoring, whether that is done through a sensor or a human inspector. However, these costs are generally offset with savings from reduced downtime as well as part and machine longevity.

If sensors are used, costs associated with the installation can add up, especially in hostile operating environments where sensors may get destroyed regularly. Some sensors may require that manufacturers modify their machinery in order to implement them, oftentimes voiding their warranty. Additionally, training employees to inspect, install, and calibrate sensors can become costly.

The time between maintenance actions can be unpredictable using this method, because parts are only replaced as needed. This makes it more difficult to plan for scheduled downtime well in advance.

Condition-based maintenance improves the usage of parts while largely protecting machines from critical failures and unscheduled downtime, but training workers and using aftermarket sensors can become expensive and time-consuming, especially if sensors must be replaced frequently. Schedule unpredictability can also lead to increased opportunity costs. This system is best implemented on machines that require frequent part replacements that are easily monitored and straightforward to fix.

Usage-Based Maintenance

What about all of those instances that aren't readily covered by preventive maintenance or for which that method would be far too excessive and expensive? Manufacturers then move toward usage-based maintenance to account for variable machine usage, create more sensible timelines, and reduce costs in the long run.

Just as calendar-based maintenance uses a set time interval to replace parts, usage-based maintenance utilizes a usage interval, eg:

- Replace the Blow mould cavity every 30 days (calendar-based maintenance)
- Change the Mould ring seal every 500 hours ran. (usage-based maintenance)

In the latter scenario, it doesn't matter if it takes you one month or one year to hit five hundred hours, the seal only needs to be replaced once it has been used to its potential and further use could cause degradation of other parts of the rotating main wheel.

Usage-based maintenance is a step in the right direction in that it accounts for actual usage over time intervals which could be arbitrary in some cases. It reduces the likelihood of over-maintenance and reduces waste. However, it can be taken further to greater effect with predictive and prescriptive maintenance.

2.3 Evaluation of maintenance

2.3.1 Overall equipment effectiveness (OEE)

OEE is used to evaluate maintenance performance. When the machines are maintained, the overall equipment effectiveness will be high. Availability rate, quality rate and performance rate are taken into account (Ahuja and Khamba, 2007; Ahuja and Kumar, 2009). Hence OEE = availability rate x quality rate x performance rate.

There is a world class goal for OEE (Table 1). When machine maintenance is done, the OEE will be close to world class standard. In a study carried out by Igbokwe and Godwin (2021) in a food and beverage manufacturing company in Anambra State, Nigeria; the OEE was 55.3% which is below the world class standard. Another study in four companies in Akure, Ondo State showed that machine maintenance was poor resulting in low productivity

Table 1: World class overall equipment effectiveness

OEE factor	World class rate (%)
Availability	>90
Performance rate	>95
Quality rate	>99
OEE	85

Source: Jain *et al*., 2013

Availability rate

Here, equipment failure, set up and adjustment results in losses and it is calculated as the ratio of operating time to loading time.

$$\text{Availability} = \frac{\text{Planned runtime-planned down time}}{\text{planned run time}} \times 100$$

Performance rate

Performance rate accounts for losses due to idle time and minor stoppages and is calculated as ratio of net operating time to operating time and it is calculated as follows:

$$\text{Performance rate:} \quad \frac{\text{Total actual amount of product}}{\text{Target amount of product}} \text{ X } 100$$

Quality rate: It factors is the defects in process and reduced yield and is defined as ratio of valuable operating time to net operating time calculated as follows:

$$\text{Quality rate} = \frac{\text{Processed quantity –defective quantity}}{\text{processed quantity}} \text{x}100$$

2.4 Existing preventive model

PM models are categorized into three groups: age reduction models, hazard rate reduction models, and a hybrid of both.

• *Age reduction models* These models are developed by considering age reduction in the hazard function . Using the concept of age reduction, we might say that a certain

PM has reduced the virtual age of a maintained system to a younger age, for example, from an age of 12 years old to a condition as good as 5 years old. That is, the hazard function changes from before a PM to after a PM.

Hazard rate models these models are developed considering the reduction of the hazard rate of a system. This group of models assumes that the hazard rate of a system changes, for example, from before a PM to after a PM.

• *Hybrid models* these models are combinations of the above two groups; the hazard rate changes from to, for example. the Malik model (1979), the improvement of the PM is that the year old system is no longer that old, and its post-maintenance age is reduced in terms of its reliability, where varies between zero and one. The effect of the maintenance can also be expressed by hazard functions as follows.

Nakagawa (1988) proposes two PM models: one is an age reduction model, and the other is a hazard rate reduction model. In what follows, these two models are referred to as NAK1, and NAK2, respectively.

2.5 Maintenance studies in Nigeria

A study by Ebomah and Ugbomhe (2021) using manufacturing firms in the Nigerian Stock Exchange showed that maintenance had significant positive effect on return on investment.

Another study in Akure by Bolaji and Adejuigbe (2012) on the appraisal and the evaluation of maintenance culture, enhancing productivity through optimal machine availability and utilization in manufacturing industries used Mathematical models to assess the performance of maintenance personnel in the four prominent manufacturing industries in Akure, Nigeria. The results obtained indicated that production machines are already getting old, thereby resulting to frequent breakdown. Maintenance analysis were generally poor due to poor review or monitoring of maintenance performance, low degree of planning, improper execution of preventive maintenance, lack of necessary spare parts, and inadequate maintenance personnel. The number of time of breakdown of the machines lies between 2 to 9 times per year. Number of overtime per day lies between 1 to 12 hours and it varies from one machine to another. The average age of the machines is 15years

In another study by Chikezie *et al.* (2017) using manufacturing industries in Benue State, preventive maintenance influences the product quality of the selected firms. Questionnaire was used to obtain data on maintenance culture and performance of firm. The correlation coefficient showed a value of 0.51 regarded as moderate relationship, the significant test shows that maintenance culture significantly influences product quality of the selected firms at 5% level of significance.

A study among 279 staff in Ebonyi State using rice industries showed that there was a significant association between corrective maintenance and machine availability with a correlation coefficient of 0.984. (Onyeizugbe e*t al.,* 2018). The study concluded that maintenance culture has a vital role to play in the performance of manufacturing outfits.

In a food and beverage manufacturing company based in Anambra state, Nigeria, the overall equipment effectiveness was 55.3% the manufacturing organization under study is in an average condition and there is a required urgent improvement of maintenance policies and strategies otherwise it will be difficult for the manufacturing organization to sustain it.

2.6 Major maintenance variables

The variables in this study includes

1. Down time: this is when a piece of machinery or equipment is offline, whether due to equipment failure or servicing requirements such as replacement/replacement of parts or maintenance.
2. Breakdown: This is a cessation of normal operation. The act of disrupting an established order so it fails to continue.
3. Type of maintenance done: This is can be preventive, corrective etc.
4. Total production volume: the quantity of materials produced.
5. Target production volume: the anticipated quantity of product
6. Number of maintenance per year
7. Year of purchase of the various machines.

3. Methodology

With authorization from the management of the companies, the management information system and maintenance procedures for the Caser/Packer machine in XNBC and the Filler machine (1650CPH) by Krones Germany were evaluated in the work orders, logbooks, operating statistics, and production reports including target volume and actual volumes. A thorough analysis was conducted to obtain primary data. Production and maintenance activities related to the Caser/Packer and Filler machine were gathered from 2017 to 2021.

4. Data analysis

Data was analyzed using Microsoft excel. The type of maintenance conducted was recorded. The availability rate, performance rate and quality rate were calculated.

4. Results and Discussion

4.1 Presentation of results this study was for a period of five years (year one: 2017; year two: 2018; year three: 2019; year four: 2020; years five: 2021)

Table 2: Data obtained from the company (Company XNBC) Filler Machine)

Variables	2017	2018	2019	2020	2021
Name of machine	Filler	Filler	Filler	Filler	Filler
Year of purchase, installed and commissioned?	2008	2008	2008	2008	2008
Type of maintenance	Preventive Usage based	Preventive Usage based	Preventive Usage based	Preventive Usage based	Preventive Usage based
Total number hours of breakdown per year(hours)	123.66	107.33	146.33	153.4	108.5
Number of hours of operation per year(hours)	2386.67	2462.56	3626.02	2028.80	3481.41
Number of hour of overtime per year	242	201	166	143	129
Target amount of product per year	3102244	3505644	4799560	5234767	4878455
Actual amount of product per year	3230017	3794995	6207177	3467081	5543752
Quantity of defective product per year	1213	983	1310	643	4891
Machine capacity (CPH)	1650	1650	1650	1650	1650

Table 3 shows that the machine was purchased in 2008 and the type of maintenance approaches carried out were preventive or usage based maintenance. The machine has a capacity of 1650CPH

Table 3: General information of the filler machine

Variables	Information
Name of machine	Filler
Year of purchase	2008
Type of maintenance	Preventive and usage based
Capacity of machine	1650CPH

Figure 3 shows that the availability rate of the filler machine. The availability rate was highest in the year five 96.9% while it was lowest in year four (93.0%)

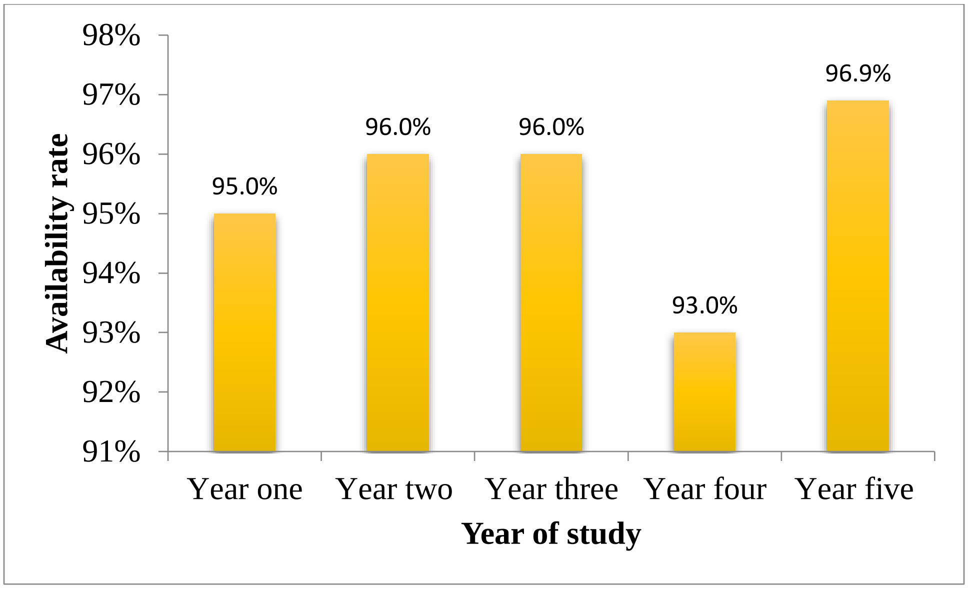

Figure 3: Availability rate of the filler machine

Figure 4 shows that performance rate was least in year four (2020 (66.2%) while it was highest in year three (129%)

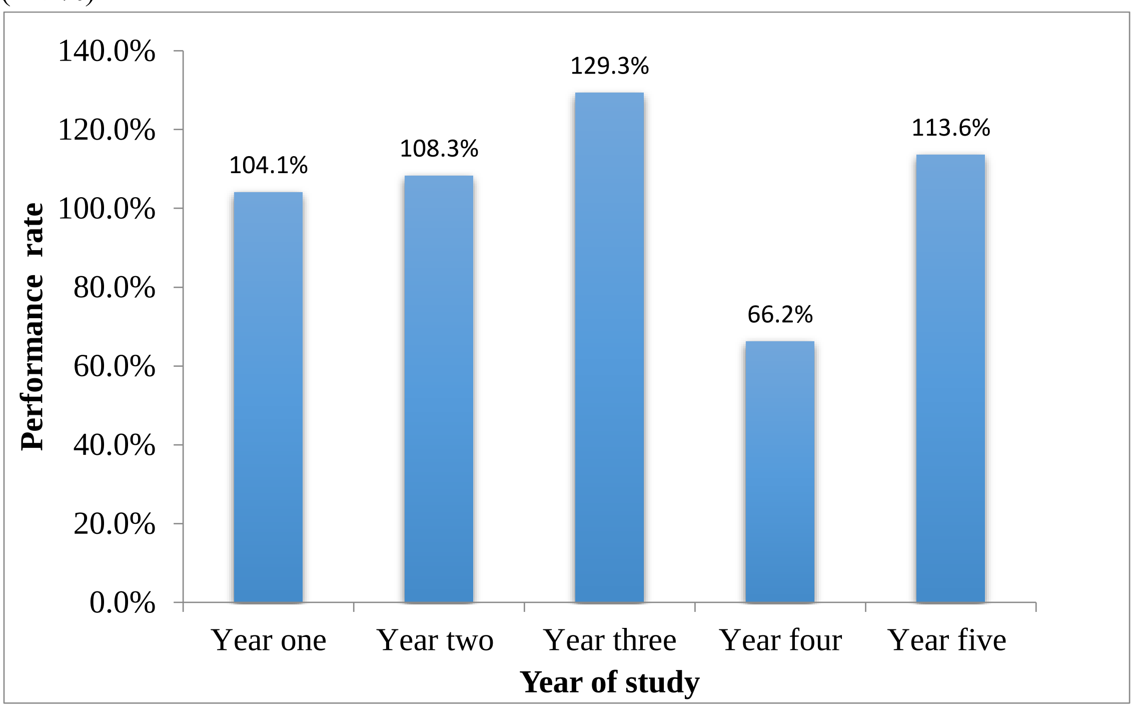

Figure 4: Performance rate of the filler machine

Table 4 shows that the quality rate was 99.9% all through the five years of study.

Table 4: Quality rate of the filler machine

Year of study	Quality rate (%)
Year one (2017)	99.9
Year two (2018)	99.9
Year three(2019)	99.9
Year four (2020)	99.9
Year five (2021)	99.9

Table 5: Data obtained from the company (Company XNBC) Packer/Caser Machine)

Variables	2017	2018	2019	2020	2021
Name of machine	Packer/Caser	Packer/Caser	Packer/Caser	Packer/Caser	Packer/Caser
Year of purchase, installed and commissioned?	2008	2008	2008	2008	2008
Type of maintenance	Preventive Usage based	Preventive Usage based	Preventive Usage based	Preventive Usage based	Preventive Usage based
Total number hours of breakdown per year(hours)	154.5	117.66	158.3	264.5	128.6
Number of hours of operation per year(hours)	2392	2472.5	3635	2048.3	3498.3
Number of hour of overtime per year	249	221	169	183.5	148
Target amount of product per year	3,102,244	3,505,644	4,799,560	5,234,767	4,878,455
Actual amount of product per year	3,219,900	3,694,895	5,207,100	3,467,092	5,043786
Quantity of defective product per year	1243	998	1310	893	4851
Machine capacity (CPH)	1650	1650	1650	1650	1650

Table 6 shows that that the packer/caser was purchased in 2008 and the type of maintenance approaches carried out were preventive and usage based maintenance. The machine has a capacity of 1650CPH

Table 6: General information of the Packer/Caser machine

Variables	**Information**
Name of machine	Packer/Caser
Year of purchase	2008
Type of maintenance	Preventive and usage based
Capacity of machine	1650CPH

Table 7 shows that availability (96.3%) and performance rates (103%) of packer/Caser machine were highest in year five while they were least in year four: 87.0% and 66.2% respectively.

Table 7: Availability rate, Performance rate and Quality rate of the XNBC Packer/Caser machine.

Year of Study	Availability Rate (%)	Performance Rate (%)	Quality Rate (%)
Year One (2017)	93.5%	103%	99%
Year Two (2018)	95.2%	105%	99%
Year Three (2019)	95.6%	108%	99%
Year Four (2020)	87.0%	66.2%	99%
Year Five (2021)	96.3%	103%	99%

Table 8: Data obtained from Company Y Ltd (Bottle Blow mould)

Variables	2017	2018	2019	2020	2021
Name of machine	Blow Mould	Blow Mould	Blow Mould	Blow Mould	Blow Mould
Year of purchase, installed and commissioned?	2014	2014	2014	2014	2014
Type of maintenance	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based
Total number hours of breakdown per year(hours)	125	130	227	397	132
Number of hours of operation per year(hours)	3024	3024	3024	3024	3024
Number of hour of overtime per year	119	118	110	102	128
Target amount of product per year	2,140,000	2,140,000	2,140,000	2,140,000	2,506,000
Actual amount of product per year	1,722,240	1,823,200	1,910,000	1,000,800	2,056,850
Quantity of defective product per year	47,760	56,800	69,150	38,200	99,150
Machine capacity (BPH)	550	550	550	550	550

Table 9 shows that the machine was purchased in 2014 and the type of maintenance approaches carried out were preventive and condition based maintenance. The machine has a capacity of 550CPH

Table 9 : General information of the Blow Mould machin

Variables	Information
Name of machine	Blow mould
Year of purchase	2014
Type of maintenance	Preventive and Condition based
Capacity of machine	550BPH

Table 10 shows that the availability rate was highest in year one (95.8%) while the performance rate was least in (46.7%) in year four. The quality rate also varied being highest in year one(97.2%).

Table 10: Availability rate, Performance rate and Quality rate of the Company Y Blow mould machine.

Year of Study	**Availability Rate (%)**	**Performance Rate (%)**	**Quality Rate (%)**
Year One (2017)	95.8%	80.5%	97.2%
Year Two (2018)	95.0%	85.1%	96.8%
Year Three (2019)	92.4%	89.2%	96.3%
Year Four (2020)	86.8%	46.7%	96.1%
Year Five (2021)	95.6%	82.0%	95.1%

Table 11: Data obtained from Company Y Ltd Monobloc – (Filler, Capper & Rinser).

Variables	2017	2018	2019	2020	2021
Name of machine	Monobloc (Filler)	Monobloc (Filler)	Monobloc (Filler)	Monobloc (Filler)	Monobloc (Filler)
Year of purchase, installed and commissioned?	2014	2014	2014	2014	2014
Type of maintenance	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based
Total number hours of breakdown per year(hours)	120	130	217.5	386	114.5
Number of hours of operation per year(hours)	3024	3024	3024	3024	3024
Number of hour of overtime per year	110.3	117.8	119.5	112	118.5
Target amount of product per year	2,136,400	2,136,400	2,136,400	2,136,400	2,500,000
Actual amount of product per year	2,006,800	2,010,600	1,898,450	1,008,500	2,403,700
Quantity of defective product per year	129,600	125,800	150,400	76,400	196,400
Machine capacity (BPH)	600	600	600	600	600

Table 12 shows that the Monobloc machine was purchased in 2014 and the type of maintenance approaches carried out were preventive and condition based maintenance. The machine has a capacity of 600CPH

Table 12: General information of the Monobloc machine

Variables	**Information**
Name of machine	Monobloc (Filler/Capper/Rinser)
Year of purchase	2014
Type of maintenance	Preventive and Condition based
Capacity of machine	600BPH

Figure 5 shows that the availability rate of the Monobloc was lowest in year 4 (2020**)**

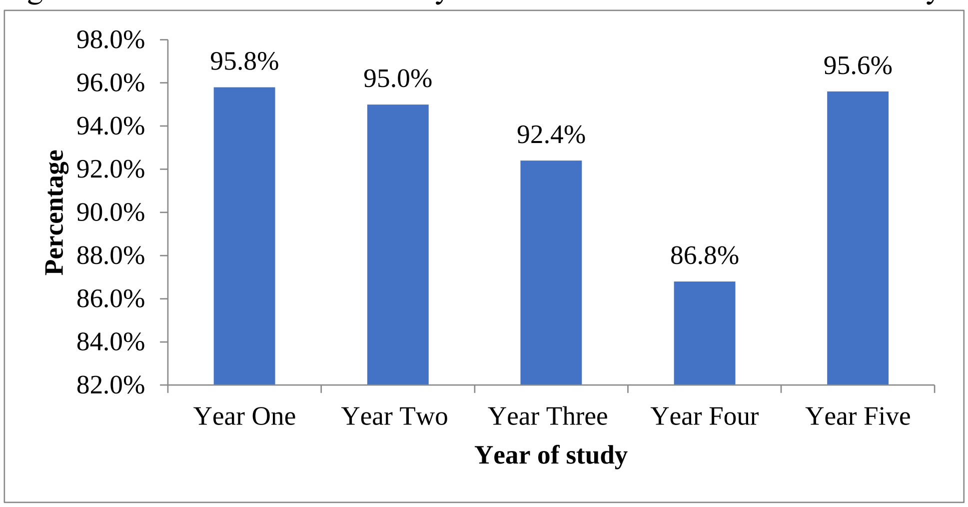

Figure 5: Availability rate of mono bloc machine (Company Y limited)

Figure 6: Performance rate of monobloc machine shows that there was high performance in 2021(year five)

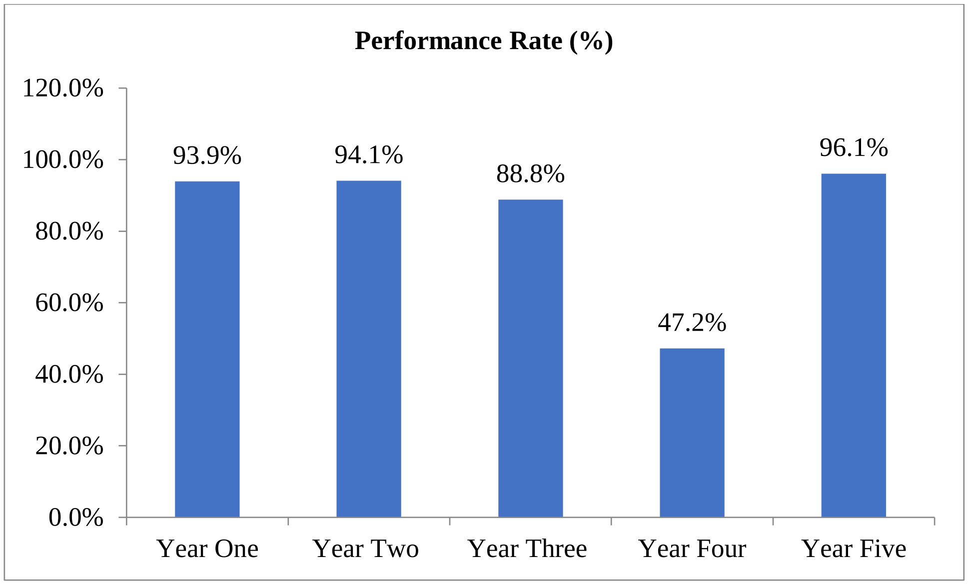

Fig 6: Performance rate of Monobloc

Table 13 shows that the quality rate of the monobloc machine varied for the different years. it was highest in year two (93.7%)and least in year five(91.8%)

Table 13 : Quality rate of the Monobloc (Filler/Capper/Rinser)

Year of Study	**Quality Rate (%)**
Year One (2017)	93.5%
Year Two (2018)	93.7%
Year Three (2019)	92.0%
Year Four (2020)	92.4%
Year Five (2021)	91.8%

Table 14: Data obtained from Company Y Ltd --- Packer/Caser machine.

Variables	2017	2018	2019	2020	2021
Name of machine	Packer/Caser	Packer/Caser	Packer/Caser	Packer/Caser	Packer/Caser
Year of purchase, installed and commissioned?	2014	2014	2014	2014	2014
Type of maintenance	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based
Total number hours of breakdown per year(hours)	321.5	165.8	285.5	364.3	216

Number of hours of operation per year(hours)	3024	3024	3024	3024	3024
Number of hour of overtime per year	110	117	118	113.5	116.3
Target amount of product per year	178,000	178,000	178,000	178,000	201,600
Actual amount of product per year	149,200	156,400	143,100	82,500	173,300
Quantity of defective product per year	12,300	15,600	11,800	7,500	17,300
Machine capacity (BPH)	600	600	600	600	600

Table 15: General information of the Packer/Caser machine

Table 15 shows that the packer/caser machine was purchase in 2014 and has a capacity of 600BPH. Type of maintenance done was preventive and condition based

Variables	**Information**
Name of machine	Packer/ Caser
Year of purchase	2014
Type of maintenance	Preventive and Condition based
Capacity of machine	600BPH

Table 16: Shows the Availability rate, Performance rate and Quality rate of the Company Y – Packer/Caser

Year of Study	**Availability Rate (%)**	**Performance Rate (%)**	**Quality Rate (%)**
Year One (2017)	89.0%	83.8%	91.7%
Year Two (2018)	94.5%	87.8%	90.0%
Year Three (2019)	90.5%	80.4%	91.7%
Year Four (2020)	87.9%	46.3%	90.9%
Year Five (2021)	92.1%	85.8%	90.0%

Discussion

This study showed that the filler machine and Packer/Caser used in XNBC were effective even though they were bought in 2008 which is 14 years ago. This is contrary to the finding in Akure by Bolaji and Adejuigbe, (2012) where there was frequent machine breakdown due to poor maintenance of the 15 years old machine in the manufacturing company. The maintenance approach used by the company may have accounted for the functionability of the machine since 14 years ago. NBC Benin plant practiced a combination of different maintenance approach for the filler machine: Preventive and usage based. . The kind of maintenance practice by BONS Industries Ltd is preventive and condition based. Here, the parts of the machine are replaced when they seem to getting too worn out to continue functioning appropriately. At the time the machine is getting worn out, it may affect effectiveness. Comparing the availability and performance rates of the filler machines of NBC and Monobloc of BONS Industries Limited, the rates were better in NBC than BONS. This may be attributed to the kind of maintenance done and the technical know-how.

It is known that machine breakdown and failures affects the effectiveness of the machine. But in this study, it was shown that the filler machine was available most of the time resulting in high product manufacturing. This was also seen in the performance rate and quality rate. This finding is similar to the world class standard (Jain *et al.,* 2013) but higher than the finding by Igbokwe and Godwin (2021) in a food and beverage manufacturing company in Anambra State, Nigeria; the OEE was 55.3% .

This may be attributed to the fact that the XNBC fathoms coordinated maintenance in its operations. Being a multinational company, maintenance of the filler machines is done by both local and foreign maintenance personnel. In-fact, the producer of the machine (Krones Germany) is always involved in the maintenance of the Filler machine and other XNBC equipment. In Company Y limited, maintenance was done by the locally available technicians. More training may be needed by these technicians and the producers of the machine should be involved in the maintenance.

It was however seen that in year four (2020), the availability rate was lower than other years in both companies. This may be attributed to COVID 19 pandemic which limited the availability of foreign man- power to assist in the machine maintenance in the case of Nigerian Bottling Company Ltd and lay off of some Technicians/reduction of manpower by Company Y Limited. Airports, sea ports and land travels were closed down during the lock down to prevent the spread of the infection. This indirectly affected the company's maintenance operations. Local markets were also closed except food markets which affected procurement of spare parts. Company Y limited which lay off some technician was also due to low market sales/share during the pandemic.

5.1 **Summary of finding**

This was a retrospective study on evaluation of maintenance in food and beverage manufacturing industries using Company (XNBC) Ltd, Company Z and Company Y Limited, Enugu. Machines for the study were Filler (krones), and Packer for XNBC while Blow Mould, Monobloc, and Packer/Caser for Company Y Limited (these are Bottling line equipment). It was found that the maintenance approaches used were preventive and usage-based approaches in XNBC while Company Y Limited used Preventive and condition based. Availability rate, performance rate and quality rates were high in both industries although XNBC was better.

5.2 C**onclusions**

The approaches used for the maintenance of these machines in these manufacturing companies are preventive and usage based in XNBC and preventive and condition based in Company Y Limited. The availability rate, performance rate and quality rate were high however performance rate was lower in the year 2020 in both companies due to reasons given above (COVID 19 Pandemic).

5.3 Recommendations

i. It is recommended that companies should carry out routine preventive maintenance and usage base maintenance since better result was obtained when compared to preventive and condition based.

ii. Local manpower should be trained on machine maintenance and in some cases of overhaul or refit, the owners/manufacturers of the machine should be involved.

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