

Optimizing technologies for pharmaceutical manufacturing in Nigeria post covid-19

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ABSTRACT

Background: The covid-19 pandemic has catalyzed numerous changes accelerating digital health transformation. Industry 4.0 is a concept that represents the adoption of techniques and processes allowed by industrial digitization.

Objective: This study evaluated the impact of covid-19 on Pharmaceutical Industries in Nigeria. It also assesses the awareness and adoption of emerging technologies by Pharmaceutical industries in Nigeria post-covid-19.

Methods: This descriptive cross-sectional study was conducted among Pharmaceutical manufacturing Industries in Nigeria using structured electronic questionnaires for data collection using Google Form software. Data obtained were examined and analyzed by SPSS version 22. Analysis was done using descriptive statistics and results were presented in tables and figures. Chi-square analysis was used to determine the association between variables.

Results: The results show that covid-19 impacted the Nigerian Pharmaceutical Industry in some areas, especially in sourcing and distributing materials. Only 50% indicated any knowledge of 4.0. Their knowledge was related to the size of the companies ($p = 0.001$). Internet of Things (IoT) and mobile technologies are the most used and were also believed to be the most relevant while Radio Frequency Identification (RFID) and advanced robotics are the least used. The adopted technologies by companies were not associated with the size of the companies ($p > 0.05$). Lack of experts for training and lack of finance were identified as barriers to technology optimization.

Conclusion: This research provides relevant information concerning the state of awareness, adoption, or preparedness for the adoption of digital technologies among Nigerian Pharmaceutical manufacturers. A lot needs to be done to enable the adoption of Industry 4.0.

Keywords: Covid-19, digital health, industry 4.0, pharmaceutical industry.

Optimiser les technologies pour la fabrication pharmaceutique au Nigeria après covid-19

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ABSTRAIT

Contexte: La pandémie de covid-19 a catalysé de nombreux changements accélérant la transformation numérique de la santé. L'Industrie 4.0 est un concept qui représente l'adoption de techniques et de processus permis par la numérisation industrielle.

Objectif: Cette étude évalue l'impact du covid-19 sur les industries pharmaceutiques au Nigeria. Elle évalue également la sensibilisation et l'adoption des technologies émergentes par les industries pharmaceutiques au Nigeria après la covid-19

Méthodes: Cette étude transversale descriptive a été menée auprès des industries manufacturières pharmaceutiques au Nigeria à l'aide de questionnaires électroniques structurés pour la collecte de données à l'aide du logiciel Google Form. Les données obtenues ont été examinées et analysées par la version 22 de SPSS. L'analyse a été effectuée à l'aide de statistiques descriptives et les résultats ont été présentés sous forme de tableaux et de figures. L'analyse du chi carré a été utilisée pour déterminer l'association entre les variables.

Résultats: Les résultats montrent que le covid-19 a eu un impact sur l'industrie pharmaceutique nigérienne dans certains domaines, notamment en matière d'approvisionnement et de distribution de matériaux. Seulement 50 % ont indiqué avoir une connaissance de la version 4.0. Leurs connaissances étaient liées à la taille des entreprises ($p = 0,001$). L'Internet des objets (IoT) et les technologies mobiles sont les plus utilisés et sont également considérés comme les plus pertinents, tandis que l'identification par radiofréquence (RFID) et la robotique avancée sont les moins utilisées. Les technologies adoptées par les entreprises n'étaient pas associées à la taille des entreprises ($p > 0,05$). Le manque d'experts pour la formation et le manque de financement ont été identifiés comme des obstacles à l'optimisation technologique.

Conclusion: Cette recherche fournit des informations pertinentes sur l'état de sensibilisation, d'adoption ou de préparation à l'adoption des technologies numériques parmi les fabricants de produits pharmaceutiques nigériens. Il reste beaucoup à faire pour permettre l'adoption de l'Industrie 4.0.

INTRODUCTION

The covid-19 global pandemic in 2020 led to the inevitable lockdown of the economy across affected countries thereby affecting the economy globally due to a decrease in the production and exportation of raw materials as well as finished products (drugs) across different Countries, resulting in supply chain and market disruption. Pharmaceutical manufacturers were faced with the priorities of keeping their staff safe and transitioning majorly to a remote work environment as well as ensuring ongoing operation of facilities for essential medicines. Introducing measures such as remote working, dual and tactical sourcing strategies, remote audits, and structured market intelligence as ways out. Regulators on their part are tightening up the rules and guidance for manufacturers and closely monitoring the pace of adoption of digital technology and advanced manufacturing platforms. Therefore, Pharmaceutical manufacturers continue to respond not only to the challenges that the ongoing global crisis has presented but also to evolving obstacles and hurdles that are typical in such a highly regulated sector.¹

The local Pharmaceutical manufacturing industry, consisting of over 120 companies² is one of the largest in West Africa and accounts for about 60% of the market share in West Africa, but the industry is facing many problems such as poor infrastructural and unreliable utilities, scarcity of skilled workers, poor access to finance, lack of appropriate government incentives, policy incoherence by the government, poor demand due to robust competition from Asian companies particularly China, high cost of doing business as a result of imported and expensive production inputs, regulatory problems, etc. It is currently able to meet 25 percent of local demand. The remaining 75 percent of the market is dominated by imports from Asian companies such as China and India.³

Due to the pandemic, there were supply chain disruptions as many importers shut down their factories and closed their borders, particularly China. Therefore, local drug manufacturers could not manufacture drugs because the Active Pharmaceutical Ingredients (APIs) could not be sourced. In addition, India temporarily banned the export of some generic drugs as the government was worried about shortages in its domestic market. Similarly, different countries enforced export restrictions.⁴

Industry 4.0 also known as the fourth industrial revolution is a German strategic initiative. It is a concept that

represents the adoption by industry of techniques and processes allowed by digitization. Industry 4.0 is considered a new industrial stage in which several emerging technologies are converging to provide digital solutions. It creates a world in which virtual and physical systems of manufacturing flexibly cooperate at the global level.⁵ It involves technologies interacting across the physical, digital, and biological domains i.e. smart and connected machines and systems as well as nanotechnology, quantum computing, etc. In the context of Industry 4.0, manufacturing systems are updated to an intelligent level. Intelligent manufacturing takes advantage of advanced information and manufacturing technologies to achieve flexible, smart, and reconfigurable manufacturing processes which will address the concerns posed by a dynamic and global market⁵. In this way, products can be made more customer-specific which in turn creates an increase in consumer benefit.⁵ On the production side, Industry 4.0 is a collective term that involves many modern automation systems, data exchanges, and production technologies. Pillars of Industry 4.0 include cybersecurity, cloud computing, mobile technologies, machine-to-machine, 3D printing, advanced robotics, big data/analytics, Internet of Things, RFID technologies, and cognitive computing.

The last decade has introduced the current industrial revolution called Industry 4.0. Some countries, like China, have deployed and tapped into various features of this technology. Although a country like South Africa seems to be the champion deployment of technologies for Industry 4.0 in Africa, other countries on the continent of Africa continue to lag.⁶

The big question therefore remains, is the local Pharmaceutical industry in Nigeria prepared for the shift occasioned by the covid-19 pandemic? This research provides insight into the adoption of Industry 4.0 by Nigerian Pharmaceutical manufacturers. This research aims to evaluate the impact of covid-19 as well as the awareness and adoption of emerging technologies among Pharmaceutical Industries in Nigeria post-covid-19. Specifically highlighting the impact of covid-19 on Pharmaceutical industry operations, investigating the perspective of manufacturers on available technologies and implementation using the Industry 4.0 concept, and identifying barriers to technology optimization.

METHODS

2.1 Study Design

A cross-sectional survey of Pharmaceutical manufacturing companies in Nigeria at the time of data collection was performed and the responses of stakeholders were obtained. A convenience sampling technique was used to recruit the study participants involving all members of the Pharmaceutical Manufacturers Group of the Manufacturers Association of Nigeria (PMG-MAN) and the Association of Industrial Pharmacists of Nigeria (NAIP). Pre-testing of the questionnaire was done among five companies. The study participants were required to fill out the questionnaire within the 1 month stipulated for the study.

2.2 Data collection

An online questionnaire consisting of 25 structured, clear, non-biased, relevant questions was chosen as a way of collecting data using the Google form platform targeting

120 companies across Nigeria that are members of PMG-MAN and NAIP. Questions focused on the social demographics of the companies, the impact of covid-19, related questions on Industry 4.0, and barriers to optimizing technology. The participants were assured of confidentiality of their responses and informed consent of the participants was also sought at the beginning of the questionnaire.

2.3 Data analysis

Survey analytics were generated automatically by the Google Forms software, providing visual representations of the results using tables and bar charts. Data obtained were examined, exported to SPSS version 22 software, coded, and investigated for some statistically relevant relationships evident in the responses. Chi-square analysis was adopted.

RESULTS

The survey received responses from 54 Pharmaceutical organizations in approximately 1 month.

Table 1: Socio-demographics of respondents' companies

Variables	Frequency (%)
Size of organization	
Small (<100 employees)	33 (61.1)
Medium (100 – 500 employees)	18 (33.3)
Large (> 500 employees)	3 (5.56)
Organization's main business activity	
Formulation manufacturer	48 (88.9)
API/ Bulk drug supplier	2 (3.7)
Importation	4 (7.4)
Companies' years of experience	
< 5 years	21 (38.9)
6 to 9 years	18 (33.3)
> 10 years	15 (27.8)
Companies' year of establishment	
< 1980	6 (11.1)
1980 to 2000	27 (50.0)
> 2000	21 (38.9)
GMP Status	
National	33 (61.1)
No GMP	6 (11.1)
No response	15 (27.8)
Ownership structure	
Combined (Local and foreign)	4 (11.1)
100% Local	45 (83.3)
Foreign	3 (5.6)
Both (Local and foreign)	12 (22.2)

Table 1 shows sociodemographic data of the companies to which the respondents belong. The majority of respondents work in small-size organizations (61.1%), are formulation manufacturers (88.9%), have national GMP status (61.1%) and are 100% locally owned (83.3%). Only 15 (27.8%) had more than 10 years of experience and half of the companies were established between 1980 and 2000.

Table 2: Impact of covid-19 on various processes engaged by pharmaceutical companies in Nigeria

Impact	Moderately unfavorable (%)	Highly unfavorable (%)	Neutral (%)	Moderately favorable (%)	Highly favorable (%)
Sales and marketing	27 (50.0)	9 (16.7)	3 (5.6)	15 (27.8)	0
Sourcing of raw materials	21 (38.9)	33 (61.1)	0	0	0
Sourcing of equipment	21 (38.9)	27 (50.0)	6 (11.1)	0	0
Facility management	21 (38.9)	6 (11.1)	24 (44.4)	3 (5.6)	0
Research and development	12 (22.2)	15 (27.8)	24 (44.4)	3 (5.6)	0
Production	18 (33.3)	15 (27.8)	12 (22.2)	6 (11.1)	1 (1.9)
Human resources	27 (50.0)	6 (11.1)	21 (38.9)	0	0
Planning	30 (55.6)	15 (27.8)	12 (22.2)	6 (11.1)	1 (1.9)
Product Licensing/ registration	24 (44.4)	24 (44.4)	6 (11.1)	0	0
Pharmacovigilance	24 (44.4)	6 (11.1)	24 (44.4)	0	0
Materials	15 (27.8)	9 (16.7)	27 (50.0)	3 (5.6)	0

Table 2 shows the impact of covid-19 on various processes engaged by Pharmaceutical companies in Nigeria. Some of the processes found to be highly unfavorable as a result of covid-19 by the majority of the respondents include sourcing of raw materials (61.1%) and sourcing for equipment (50.0%) while processes like sales and marketing (50.0%), human resources (50.0%) and planning (55.6%) were viewed as moderately unfavorable.

Table 3: Outcomes of the effects of covid-19 on manufacturing operations

Outcomes	Yes (%)	No (%)	Not sure (%)
Reduction in cash flow/ source of finance	48 (88.9)	3 (5.6)	3 (5.6)
Need to downsize	21 (38.9)	24 (44.4)	9 (16.7)
Customer management challenge	24 (44.4)	21 (38.9)	9 (16.7)
Reduction in sales/ revenue	27 (50.0)	12 (22.2)	15 (27.8)
Increased collaboration with other organization	7 (13.0)	7 (13.0)	4 (7.4)
Increased manufacturing capabilities	6 (11.1)	45 (83.3)	3 (5.6)

Table 3 shows the outcome of the effects of covid-19 on manufacturing operations according to respondents. The majority of respondents agreed that the covid-19 pandemic caused a reduction in cash flow and sources of finance (88.9%); a reduction in sales and revenue (50.0%) and there were customer management challenges (44.4%). On the other hand, the majority of respondents agreed that the covid-19 pandemic did not result in increased manufacturing capabilities (83.3%).

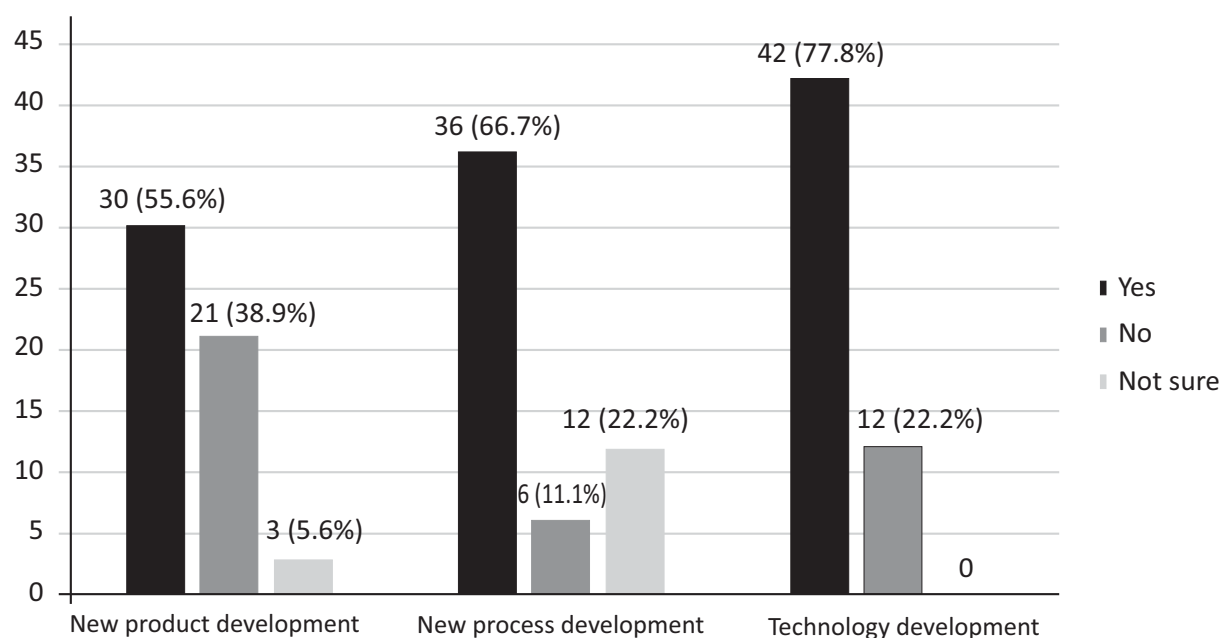
Table 4: Possible organizational measures to mitigate the effect of the covid-19 pandemic

Measures	Yes (%)	No (%)	N	Not sure (%)
Implement new technologies (web/mobile based) to sustain services	30 (55.6)	9 (16.7)		15 (27.8)
Strengthen supply chain management	42 (77.8)	6 (11.1)		6 (11.1)
Speed up digital transformation	21 (38.9)	12 (22.2)		21 (38.9)
Speed up product development	24 (44.4)	18 (33.3)		12 (22.2)
Invest more in online business	12 (22.2)	21 (38.9)		21 (38.9)
Optimize human resources	52 (96.3)	0		2 (3.7)
Strengthen collaboration with institutions and community Pharmacists	35 (64.8)	7 (13.0)		12 (22.2)

The possible organizational plans to mitigate the effect of the covid-19 pandemic according to respondents are as stated in Table 4. The majority agreed that optimizing human resources (96.3%), strengthening supply chain management (77.8%), strengthening collaboration with institutions and community Pharmacists (64.8%), and implementing new technologies to sustain services are among measures that can mitigate the effect of covid-19 pandemic. About 38.9% of respondents however disagreed that measures should include investment more in online business.

3.1 Respondents' awareness of the term "INDUSTRY 4.0"

When asked about their awareness of Industry 4.0, 27 (50.0%) of the respondents said they were aware, 21 (38.9%) said they were not while 6 (11.1%) did not respond to the question.

**Figure 1: Strategic plan developments post-covid-19 by Pharmaceutical companies in Nigeria**

The majority of the respondents are into new product development, new process development, and technology development (55.6%, 66.7%, and 77.8% respectively) as their strategic plan developments post-covid-19 according to Figure 1.

Table 5: Perception of respondents on the usefulness of Industry 4.0 technologies in pharmaceutical companies in Nigeria

Technologies	Not useful (%)	Moderately useful (%)	Very useful (%)
Big data and analytics	21 (38.9)	0	33 (61.1)
Cybersecurity	21 (38.9)	6 (11.1)	27 (50.0)
Cloud computing	24 (44.4)	3 (5.6)	27 (50.0)
Cognitive computing	24 (44.4)	3 (5.6)	27 (50.0)
RFID technologies	33 (61.1)	3 (5.6)	18 (33.3)
Mobile Technologies	12 (22.2)	6 (11.1)	36 (66.7)
Internet of Things	12 (22.2)	12 (22.2)	30 (55.6)
Advanced robotics	30 (55.6)	9 (16.7)	12 (22.2)
3D printing	30 (55.6)	9 (16.7)	12 (22.2)
Machine to Machine	21 (38.9)	9 (16.7)	24 (44.4)

Table 5 shows the result of the respondents' perception of the usefulness of the various 4.0 technologies in the pharmaceutical companies in Nigeria. The majority (66.7% and 61.1% respectively) agreed that mobile technologies and big data and analytics are very useful, while half of the respondents agreed that cybersecurity, cloud computing, and cognitive computing are very useful. Internet of Things was considered very useful by 55.6% of respondents.

Table 6: Operational Industry 4.0 Technologies in Pharmaceutical Companies post-covid-19 in Nigeria

4.0 technologies	Yes (%)	No (%)	Not sure (%)
Big data and analytics	15 (27.8)	24 (44.4)	15 (27.8)
Cybersecurity	21 (38.9)	21 (38.9)	12 (22.2)
Cloud computing	18 (33.3)	18 (33.3)	18 (33.3)
Cognitive computing	6 (11.1)	30 (55.6)	18 (33.3)
RFID technologies	0	21 (38.9)	33 (61.1)
Mobile Technologies	39 (72.2)	9 (16.7)	6 (11.1)
Internet of Things	30 (55.6)	9 (16.7)	15 (27.8)
Advanced robotics	0	42 (77.8)	12 (22.2)
3D printing	6 (11.1)	33 (61.1)	18 (33.3)
Machine to Machine	15 (27.8)	24 (44.4)	15 (27.8)

Table 6 shows the 4.0 technologies that are operational in Pharmaceutical companies post-covid-19 in Nigeria. About 55.6% of companies use Internet of Things, 38.9% are into cybersecurity, 33.3% engage in cloud computing while big data and analytics as well as machine to machine have only about 27.8% of companies engaged in such.

Table 7: Expected outcome from using Industry 4.0 technologies in Pharmaceutical companies in Nigeria

Expected outcomes	Yes (%)	No (%)	Not sure (%)
Strategic competitive advantage	52 (96.3)	0	2 (3.7)
Organizational efficiency and effectiveness	52 (96.3)	0	2 (3.7)
Manufacturing innovation	52 (96.3)	0	2 (3.7)
Increased profitability	51 (94.4)	1 (1.9)	2 (3.7)
Improved operations	52 (96.3)	0	2 (3.7)
Delightful customer experience	52 (96.3)	0	2 (3.7)
Improved product safety and quality	50 (92.6)	0	4 (7.4)
High initial cost	36 (66.7)	3 (5.6)	15 (27.8)
Environmental and social benefits	39 (72.2)	0	15 (27.8)
Socio-technical implications on the industry	30 (55.6)	6 (11.1)	18 (33.3)
Negative impact of data sharing in a competitive environment	18 (33.3)	15 (27.8)	21 (38.9)
Total implementation of Industry 4.0 is necessary for success	18 (33.3)	12 (22.2)	24 (44.4)
Handling employees and trade unions	18 (33.3)	12 (22.2)	24 (44.4)
Need for highly skilled labor	51 (94.4)	2 (3.7)	1 (1.9)
Organization agility	50 (92.6)	1 (1.9)	3 (5.6)
Apprehension	27 (50.0)	9 (16.7)	18 (33.3)
Cybersecurity issues	33 (61.1)	12 (22.2)	9 (16.7)
Access to international aid/ opportunities	51 (94.4)	1 (1.9)	2 (3.7)
Organization sustainability	36 (66.7)	4 (7.4)	12 (22.2)

Table 7 highlights the expected outcome from using 4.0 technologies in pharmaceutical companies in Nigeria according to respondents. The majority of respondents agreed to all expected outcomes listed with a strategic competitive advantage, organizational efficiency and effectiveness, manufacturing innovation, improved operations, and delightful customer experiences each having 96.3% positive responses by the respondents.

Table 8: Barriers to Technology Optimization in Pharmaceutical Industries in Nigeria

Barriers	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)	Not applicable (%)
Lack of experts	12 (22.2)	21 (38.9)	6 (11.1)	12 (22.2)	0	3 (5.6)
Lack of finance	9 (16.7)	30 (55.6)	9 (16.7)	3 (5.6)	0	3 (5.6)
Lack of time	3 (5.6)	3 (5.6)	30 (55.6)	12 (22.2)	0	6 (1.1)
Lack of guidance	3 (5.6)	21 (38.9)	9 (16.7)	15 (27.8)	0	6 (1.1)
Lack of interest among employees	0	9 (16.7)	15 (27.8)	21 (38.9)	6 (11.1)	3 (5.6)
Lack of interest among management	6 (1.1)	6 (1.1)	18 (33.3)	15 (27.8)	6 (11.1)	3 (5.6)
Lack of proper regulatory guidance	3 (5.6)	18 (33.3)	12 (22.2)	18 (33.3)	0	3 (5.6)

Table 8 addresses the barrier to technology optimization in Pharmaceutical Industries in Nigeria. Respondents agreed to lack of experts, lack of finance, lack of general guidance, and regulatory guidance as major recognized barriers while they disagreed with lack of interest among employees and lack of interest among management.

Table 9: Factors that can optimize technology in Pharmaceutical Industries in Nigeria

Factors	Not Useful (%)	Useful (%)	Very useful (%)
Government incentives	4 (7.4)	1 (1.9)	49 (90.7)
Skilled manpower	1 (1.9)	0	53 (98.1)
Intellectual property protection	1 (1.9)	0	53 (98.1)
Quality of local infrastructure services	1 (1.9)	2 (3.7)	51 (94.4)
Availability of capital	1 (1.9)	0	53 (98.1)
Lack of government sponsored research and development schemes	30 (55.6)	6 (11.1)	18 (33.3)
Lack of obvious demand for improvement	36 (66.7)	12 (22.2)	6 (1.1)
Time/ difficulty with national drug regulatory approvals	24 (44.4)	18 (33.3)	12 (22.2)

Respondents were asked about possible enablers of technology optimization and the majority (more than 90%) of them agreed that government incentives, skilled manpower, intellectual property protection, quality of local infrastructure services, and availability of capital are all strong factors that can optimize technology.

Table 10: Association between the size of companies and their awareness of Industry 4.0

Size of Company	Awareness of Industry 4.0		
	Yes (%)	No (%)	Maybe (%)
Large (>500 employees)	0	100	0
Medium (100 – 500 employees)	83.3	0	16.7
Small (< 100 employees)	36.4	54.5	9.1

$$X^2 = 19.643 \quad p = 0.001$$

Chi-square analysis of the association between the size of companies and their awareness of Industry 4.0 as shown in Table 10 shows a p-value of 0.001. The majority (83.3%) of medium-sized companies are aware of Industry 4.0 while the majority (54.5%) of small companies are not aware.

Table 11: Relationship of Size of Companies and Operational Industry 4.0 Technology in Pharmaceutical Companies Post covid-19

4.0 technologies	Size of companies	
	χ^2	p-value
Big data and analytics	9.705	0.138
Cybersecurity	12.002	0.062
Cloud computing	8.461	0.206
Cognitive computing	5.352	0.499
RFID technologies	3.468	0.483
Mobile Technologies	11.898	0.064
Internet of Things	14.232	0.027
Advanced robotics	8.400	0.078
3D printing	9.793	0.134
Machine to Machine	13.243	0.039

A chi-square analysis of each of the Industry 4.0 technology functional in the pharmaceutical companies against the companies' size shows that there is no relationship between the sizes and the technology analyzed ($p > 0.05$) except Internet of Things.

DISCUSSION

A total of 54 Pharmaceutical companies responded to the questionnaire representing 45% of the numbers of registered companies with PMG-MAN. This number gives a roughly good representation of the entire pharmaceutical industry in Nigeria concerning the focus of this study.

According to this survey, sourcing of materials and sourcing of equipment were the most affected manufacturing process with 61.1% and 50% of respondents agreeing that it was highly unfavorable respectively while sales and marketing were the least affected (Table 2). This is understandable given the profile of the Nigerian market. The Nigerian market imports almost all of its starting/ raw materials as well as production equipment and this may be the reason why this aspect was most affected. Sales and marketing were also largely moderately unfavorable according to Table 2 as sourcing for raw materials and equipment can hinder the production of finished products and consequently its sales which is majorly what sales and marketing is all about. Also, it will be noted that sales and marketing also happened to be most favorable when we compare with other impacts as stated In Table 2 although with a low percentage of 27.8%. The possible reason for this may be attributed to high demands for scarce finished products and essential products like hand sanitizers during the pandemic which favors sales and marketing. But even with this, products may not be readily available for sale. Generally, all the impacts as listed in Table 2 were unfavorable. The results of this survey differ from the one carried out by China Life Sciences and Health Care Team⁷, where marketing and sales activities were the most affected by the pandemic in China. China is a major producer of raw materials and equipment and as such, the pandemic is not expected to negatively affect these areas as it did with Nigeria.

This study shows that there was a reduction in cash flow with 88.9% of respondents agreeing with this outcome (Table 3). A similar result was obtained with the study conducted in China.⁷ Reduction in cash flow can also affect reduction in sales and revenue which was the second highest outcome according to Table 3 (50%). This study also revealed that increased manufacturing capabilities were not an outcome of the pandemic. This is expected since some aspects negatively affected according to this study included sourcing for raw materials and equipment which are major tools for increased manufacturing capabilities. In addition, the China study showed that supply chain disruptions were

also a noticeable outcome.⁷

Regarding plans to mitigate, unlike the China case, which showed that a larger number of companies seemed to embrace the idea of digital technologies faster, the Nigerian case showed that most had no defined plans. Only about half of respondents agreed that implementation of new technologies is a possible measure with only 38.9% agreeing that speeding up digital transformation is a way out (Table 4). This may be as a result of a lack of knowledge of the huge advantages of digital technology. The major technology focus of this study was 4.0 technology which only half of the respondents are aware of. Using the size of the company, it was discovered that more of the medium-sized companies are aware of Industry 4.0 compared to the large and small companies. About half of the small companies are not aware of Industry 4.0 (Table 10). This is statistically significant ($p < 0.05$) and thus can be concluded that the sizes of the companies are related to their awareness of Industry 4.0. Better exposure of the medium companies compared to the smaller ones may be the reason more of them are aware of these technologies. Similarly, most of the companies in Nigeria do not engage in the usage of 4.0 technologies. Only mobile technologies and Internet of Things (72.2% and 55.6% respectively) are used by the majority of respondents (Table 6). This may be because of a lack of experts and lack of finance which were identified as the major barriers to technology optimization as stated In Table 8. The sizes of the companies in relationship with the technologies available in companies were majorly not statistically significant ($p > 0.05$) except for Internet of Things which is influenced by the companies' sizes ($p = 0.027$). The scope of this work however, did not cover the level of awareness or understanding of the terms because it is possible that the meaning and application of the terms may not have been fully understood by the respondents and companies.

According to WHO, Nigerian Pharmaceutical Manufacturers face some challenges which include a weak financial base, high production costs as a result of the high cost of imported pharmaceutical ingredients and machinery, infrastructural problems, outdated technology, and weak distribution systems.⁸ In addition, no contract research organizations in West Africa have been proven to work in line with international standards, therefore the need to rely on expertise from Europe and Asia when they require bioequivalence studies or specific laboratory testing, insufficient capacity to ensure full regulatory functions in line with international standards,

including speedy registration of medicines.

Though majority of respondents perceived the 4.0 technologies as either moderately useful or very useful (Table 5) and the majority also believe that the technology will bring about most of the expected outcomes listed in Table 7. Similarly, these outcomes have also been identified by several studies as pros for the implementation of Industry 4.0 in organizations.⁹⁻¹² Education and training on recent technological advancements may help improve this area which may encourage most companies to look in the direction of adoption of more types of 4.0 technologies.

In light of a similar study where it was opined that examining the environmental perception of firms in Nigeria's manufacturing industry is important because Nigerian firms operate within a highly resource-constrained macro-economic terrain and for this reason, manufacturing firms tend to expend a disproportional percentage of their budget on infrastructure and firms' perception of their external environment will influence the frequency, intensity, and breadth of their scanning activities as well as the interpretation of trends and events in their environment which feeds into the determination of their competitive strategies, the study concluded that an organization's perception of the analyzability of the external environment would be influenced by the technology component of its industry's products, size of the domestic market, and the share of export in total sales. Could this be the reason for the current level of activity by the Nigerian Manufacturers in response to the covid-19 pandemic? Because, regardless of the rapid growth in Industry 4.0, it appears that Africa and other developing climes are still largely left behind.¹³

Some of the functions that have evolved with technology include preventive maintenance, manufacturing execution systems, production line automation, and analytical quality by design, etc. with the end goal of optimizing processes, monitoring plant performance, ensuring regulatory compliance, and minimizing downtime.¹⁴

About 55.6% of respondents were engaging in new product development and 66.7% in new process development after the COVID-19 pandemic (Figure 1). According to a related study, local production of drugs, especially the essential drugs, is identified as an important component of a long-term solution to the provision of adequate health care in developing countries and the capacity to produce drugs to meet national

health needs depends on building national capacity for innovation.¹⁵ The observation made by this study is a right step in the positive direction toward the provision of adequate medicines for Nigerians. To survive over the long term in a given external environment, an organization must have two strategic capabilities: the ability to prosper and the ability to change.¹³ Our world, becoming increasingly digitized, is a good thing from improved efficiency, enhanced quality, improved satisfaction, profitability, and better company compliance with ever-increasing, data-related regulatory requirements but how to approach our technology choices would require understanding what it entails, creating a step-by-step process with specific milestones for each activity as well as understanding the people and technologies involved.

Some countries have engaged in the use of these technologies in different aspects including the use of robotics in India to decrease the interval in operation and manufacturing time, 3D printing used in the United Kingdom to decrease side effects and improve drug compliance in medication designs, Artificial Intelligence used in the United States to replace human visual inquiry of packaging caps and vials by using machine vision technology, Cloud-based big data analysis used in China for drug consumers' orders to be studied for fine-grain research of pharmaceutical sector trend among many others.¹⁶ Industry 4.0 in these countries has provided opportunities like developing the countries economically and providing the citizens with a better income and lifestyle as well as sustainable manufacturing systems.¹⁷ These countries, however, still face many challenges ranging from availability of skilled staff, security, lack of infrastructure or environment in which the technologies of Industries 4.0 integrate, and high investment as well as data protection among others.^{16,17,18} The advances in automation, digitization, and cross-linking integration in Industry 4.0 will enable manufacturing innovation but the adoption of technologies among organizations may be based on the location of the organization, level of ICT infrastructure, culture, level of education, economic and political stability, and perceived advantage which may interfere in the value perception and level of investment in technologies of Industry 4.0.¹⁹ Most developing and least developed countries have not shown tangible efforts to embrace Industry 4.0. Although only a few of these countries have an overall initiative, almost all of them are laboring to catch up with the emerging manufacturing trend and are introducing Industry 4.0.¹⁷

Again, Figure 1 shows that the majority of companies are

also engaged in Technology development. Although the scope of this study does not aim to determine the specific type of technology development made, their response on the operational 4.0 technologies in the companies (Table 6) may give us a clue as to some of the technology development these companies are engaged in. The majority of respondents in this study identified government incentives, skilled manpower, intellectual property protection, quality of local infrastructure services, and availability of capital as factors that can optimize technology in Pharmaceutical Industries in Nigeria (Table 9). A related study underlines that the key to the successful adaptation of industry 4.0 technologies, is the ability of Governments to adopt the right policies as well as severe social problems that may get bigger making policy intervention crucial.²⁰

Currently in Nigeria, technological advancement has been at the center of discussions in the Pharmaceutical Industry; the theme of the 2021 National Conference of the Association of Industrial Pharmacists of Nigeria was "Technological Revolution- Adaptation in Industrial Pharmacy Practice". The keynote address speaker gave insight into emerging technologies, and their relevance for industrial pharmacy and encouraged Nigerian Industrial Pharmacists to adapt (review of curriculum, research, collaborate, etc.). As highlighted in this research, Governments provide the necessary infrastructure for the digital world (like the internet and communication systems) in most countries, finance, legal structures, policies, etc. However, there is a lack of a roadmap for changing the industrial infrastructure, primarily due to a lack of clarity (e.g. implementation of the 5G network and its benefits for Industry 4.0). The review indicates that Industry 4.0 is still an immature topic and has other principles characterizing it such as system integration, decentralization, interoperability, virtualization, and real-time capacity.¹⁸ The Nigerian Pharmaceutical Industry players must come together to develop a framework or roadmap to enable the required change in the technological landscape of the industry as a guarantee for innovation, sustainability, and growth. In agreement with a recent study, Nigeria must realistically anticipate and be positioned to harness the opportunities embedded in Industry 4.0 and adopt policies to cushion the negative effects of these technologies, towards maximizing the net gains from the fourth industrial revolution.¹²

CONCLUSION

The advent of the COVID-19 pandemic negatively affected the sourcing and delivery of materials, even

though demand for Pharmaceuticals was high, leading to a reduction in production capabilities. The study identified the need for more knowledge, strategic discussions, development of the concept, and planning for Industry 4.0 and its adoption among Pharmaceutical manufacturers in Nigeria as these technologies are an inevitable phenomenon. The implementation of this is playing an increasingly significant role globally in the modernization of industries including the Pharmaceutical industries.

It is evident from this study that Nigerian Pharmaceutical Manufacturers need to transform swiftly by implementing Industry 4.0 principles to survive in rapidly changing climes. This research provides insights for stakeholders by identifying gaps, opportunities, and challenges for the implementation of Industry 4.0 which is a valuable contribution to accelerate the successful adaptation of the paradigm in the current digital world recently highlighted by the covid-19 pandemic. It is recommended that periodic studies and monitoring of the technological advancement among Pharma companies is done to determine progress made as results obtained now may differ within a short period due to changing trends in the industries.

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