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A bibliometric analysis using VOSviewer: Leadership in infection prevention and control

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Abstract This study aims to analyze the development of publications about inner leader infection prevention and control in healthcare facility settings using the SCOPUS database. This study uses a bibliometric analysis approach using the VOSviewer software tool to construct and visualize a bibliometric network. Researchers screened by leading keywords in infection prevention and control in the SCOPUS database for 2003-2022. The number of publications according to the keywords initially appeared as many as 922 articles, and then after filtering, the final result was that the number of publications was 369. The development of publications on leadership in infection and prevention control in the past 20 years has continued to increase and reached its highest point in 2020. Based on the analysis results with VOSviewer and the network visualization of co-occurrence based on keywords, there are 52 items divided into 4 groups (clusters) marked with different colors. The COVID-19 pandemic did not cause publications on the topic of leaders in infection prevention and control to decrease. On the contrary, it reached its highest point in the 2003-2022 period, namely in 2020. The analysis results using the VOSviewer application show a link between leadership and infection prevention and control interesting network for further research. This can be seen in network visualization, overlay visualization, and density visualization results.

Keywords: leadership, leader, infection prevention and control, healthcare

1. Introduction

Infections that occur in hospitals, previously known as nosocomial infections (Khan et al 2017) and later known as Healthcare-Associated Infections (HAIs), are infections that are acquired as a result of the process of health services provided at healthcare facilities (Voidazan et al 2020). HAIs can occur in patients and can also be experienced by employees or officers who provide health services (Parmeggiani et al 2010). In connection with the recent COVID-19 pandemic, health service facilities are required to improve their services to realize patient safety (Patel et al 2021; Alboksmaty et al 2021). The realization of patient safety in healthcare facilities can be achieved by planning and implementing infection prevention and control efforts (Christenson et al 2006).

All employees or officers must carry out infection prevention and control efforts in a health service facility, namely by having the knowledge and ability to implement (participate) in providing health services (Bayleyegn et al 2021; Geberemariyam et al 2018). For example, healthcare facility staff who have close contact with patients or the patient care environment are nurses and cleaning services. Nurses are expected to be able to provide care to patients through the principles of infection prevention and control so that infection does not occur and achieve patient safety (Donati et al 2020).

The cleaning staff also plays an important role in preventing and controlling infections by cleaning the hospital environment (Quinn et al 2015). Especially with the COVID-19 pandemic, health service facilities must improve environmental hygiene to provide a safe and comfortable environment for all recipients of health services, including the health service providers themselves (Peters et al 2022). To achieve this, knowledge and skills are needed to be related to cleaning the environment by the principles of infection prevention and control (Doll et al 2018; Hall et al 2016).

Participation in infection prevention and control in health service facilities so that they can run well and achieve the expected goals, namely the realization of security and safety for all people in health service facilities, especially the creation of patient safety, a team or organization that is specifically responsible for infection prevention and control activities (Castro-Sánchez and Holmes 2015). The organization will run optimally if the roles and functions of the leader function properly (Saint et al 2010). A leader in an infection prevention and control organization is very important because, in addition to mobilizing its members to carry out their duties and responsibilities, they must also be able to solve problems related to infection prevention and control problems (Knobloch et al 2018).

This research aims to analyze the development of publications about leaders in infection prevention and control in the healthcare setting for 20 years (2003-2022) using data accessed on SCOPUS. The topic is interesting to remember that

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prevention, and control is very important to implement in healthcare facilities, and the role of a leader is an important factor in infection prevention and control efforts, especially with the COVID-19 pandemic in the past 3 years.

1.1. Literature review

1.1.1. Healthcare-associated infections (HAIs)

The incidence of infection in healthcare facilities, which was previously known as a nosocomial infection, is now better known as Healthcare-Associated Infections (HAIs), which is important to note and manage with a good and correct strategy by all units in healthcare facilities (Haque et al 2020), to provide security and safety for all health workers, employees, patients, and visitors to health service facilities (Al-Tawfiq and Tambyah 2014). HAIs are infections that occur during the process or as a result of health services in healthcare facilities (Voidazan et al 2020). HAIs incidents must be prevented or dealt with immediately if they are found, so the hospital as a healthcare facility must have an organization responsible for infection prevention and control to prevent HAIs from occurring or be able to take steps to deal with HAIs when incidents of HAIs are found (Castro-Sánchez and Holmes 2015).

All employees in a healthcare facility, especially health workers, must understand and participate in infection prevention and control activities, especially those directly involved in patient care (Bessesen et al 2021). It is not enough to be equipped with knowledge about infection prevention and control, and health workers must be able to implement and comply with infection prevention and control efforts (Ashinyo et al 2021; Alhumaid et al 2021). Apart from implementing infection prevention and control when providing services to patients, health workers must also participate in the cleanliness of the room and environment of healthcare facilities (Curryer et al 2020). In addition, the patient must also carry out involvement in infection prevention and control efforts (Agreli et al 2019). To support involvement in infection prevention and control in healthcare facilities, a team or organization is needed that is responsible for this (Knobloch et al 2019).

1.1.2. Organization of infection and prevention control in healthcare

The infection prevention and control organization can take the form of a team or committee, according to the capacity of a hospital's resources. This is to what is stated in the Managerial Guidelines for Regulation of the Minister of Health of the Republic of Indonesia Number 27 of 2017 concerning Guidelines for Infection Prevention and Control in Health Service Facilities, which states that Infection prevention and control activities in health service facilities is a quality standard of service and is important for patients, healthcare workers, and visitors. All healthcare facilities must carry out infection control to protect patients, health workers, and visitors from infection due to cost-effectiveness (Hessels et al 2016). Implementation of infection and prevention control in health service facilities must be managed and integrated between the structural and functional of all departments/installations/divisions/units by forming an organization by the philosophy and objectives of infection and prevention control in the form of a infection and prevention control Team or Committee.

One of the main activities of infection prevention and control organizations in healthcare facilities is surveillance (Khan et al 2017), especially during the COVID-19 pandemic that has occurred in the last three years (Choi et al 2021). According to the Regulation of the Minister of Health of the Republic of Indonesia Number 27 of 2017, surveillance is an activity of systematic and continuous observation of data and information about the incidence of diseases or health problems and conditions that affect the occurrence and transmission of diseases or health problems to obtain and provide useful information directing effective and efficient infection control and control measures. Surveillance must be carried out every day or every time there is a patient service/care process carried out by trained health workers, namely the Infection Prevention and Control Nurse (IPCN) (Asmara et al 2019) and assisted the Infection Prevention and Control Link Nurse (IPCLN) (Ward 2016; Peter et al 2018).

Surveillance will provide information to relevant parties about data on HAIs events that can be used as analysis material to find the causes of HAIs events. Many studies have discussed the causes of HAIs in healthcare facilities, one of which is in a hospital. The incidence of HAIs in hospitals can be caused by the colonization of pathogens or microorganisms, which can be a source of infection, as stated in a study (Weber et al 2013), so it is necessary to increase environmental cleaning followed by disinfection (Quinn et al 2015). Especially with the recent COVID-19 pandemic, hospitals are required to carry out environmental management properly and correctly by the principles of infection prevention and control (Dietz et al 2020; Yen et al 2020). Officers closely related to environmental management in hospitals are environmental health workers (sanitarians), IPCN, and cleaning services; in many studies, they are called Environmental Service Workers (ESW).

Janitors (cleaning service) are officers who directly carry out surface cleaning or environmental cleaning in all areas of the hospital, so good skills are needed to carry out safe, good, and correct cleaning techniques. To achieve these technical cleaning skills, good and correct perception, attitude, understanding, or knowledge regarding the principles of infection prevention and control and the principles of cleaning and disinfecting the hospital environment are needed for hospital cleaners (Matlow et al 2012; Allen et al 2018). One example of the knowledge and understanding that must be given to hospital cleaners is related to standard precautions (Wong et al 2021).

1.1.3. Leadership in healthcare system

The healthcare system requires a leader who can coordinate and integrate all elements in the health service facility properly, efficiently, and effectively to create professional and safe health services for patients, families, hospital visitors, and employees (Baker and Denis 2011). Leaders who are effective in running and leading a health service facility are leaders who can create, improve, or maintain the quality of health services that are oriented towards realizing safety (safety), especially for patient safety (patient safety) (Kumar and Khiljee 2016).

Leaders in health service facilities are also said to be effective if they can create a work culture in which health workers providing health services work professionally and by the code of ethics of each profession (Sakr et al 2022). The COVID-19 pandemic in the past 3 years has required leaders in health service facilities to continue to make changes, adjustments, improvements, and improvements to sustainable health services (Graham and Woodhead 2021). The improvement and improvement of health services must, of course, be balanced with improvements and increased communication between care providers or health services, so a leader is needed to make this happen (Leach et al 2021).

1.1.4. Leadership in infection and prevention control

In the era of the COVID-19 pandemic, hospitals, through management in collaboration with environmental health officers, IPCN, and related units, must be able to take appropriate steps or strategies in terms of managing, monitoring, and evaluating the performance of hospital cleaners to be able to clean the environment according to standards (Hall et al 2020). Monitoring and evaluation are carried out by organizations that are specifically responsible for infection prevention and control efforts (Griffiths et al 2009). These infection prevention and control organizations can work well if the role and function of the leader can run well too, especially with The recent COVID-19 pandemic required creativity, activeness, involvement and the presence of a leader (Crain et al 2021).

A good leader is a leader who is capable of solving problems, especially in terms of infection prevention and control efforts, to prevent or reduce the occurrence of infections resulting from the provision of health services to patients, families, hospital visitors, and employees (Knobloch et al 2018). The role of the leader in an infection prevention and control organization is essential, considering that an organization cannot run well and optimally if the functions and duties of the leader are not running well and optimally either. Leaders are responsible for ensuring, supervising, and evaluating that infection prevention and control efforts can work properly and effectively so that they can provide health services by prioritizing patient safety (Ginsburg et al 2010).

2. Materials and Methods

This study analyzes evidence-based developments about leaders in infection prevention and control using a database online SCOPUS. The database was analyzed using the VOSviewer software tool to construct and visualize a bibliometric network using a bibliometric approach. The VOSviewer software tool used is version 1.6.18 was released on January 24, 2022 which is a product of Leiden University's Center for Science and Technology Studies (CWTS), The Netherlands. Researchers screened publications about the leader in infection prevention and control in the SCOPUS database in the 2003-2022 year range.

The researchers screened the database for 20 years to get a broad picture of developments in writing or publications related to leaders in infection prevention and control. Researchers filter publications by determining restrictions, including year, subject area, document type, keywords, and language. The final number of publications after the screening was 369 articles from the initial number before the screening of 922 articles. The filtering results are then exported in a CSV file format. Furthermore, the file is analyzed using VOSviewer software. The research method the researcher used in compiling this bibliometric is more clearly explained in Figure 1.

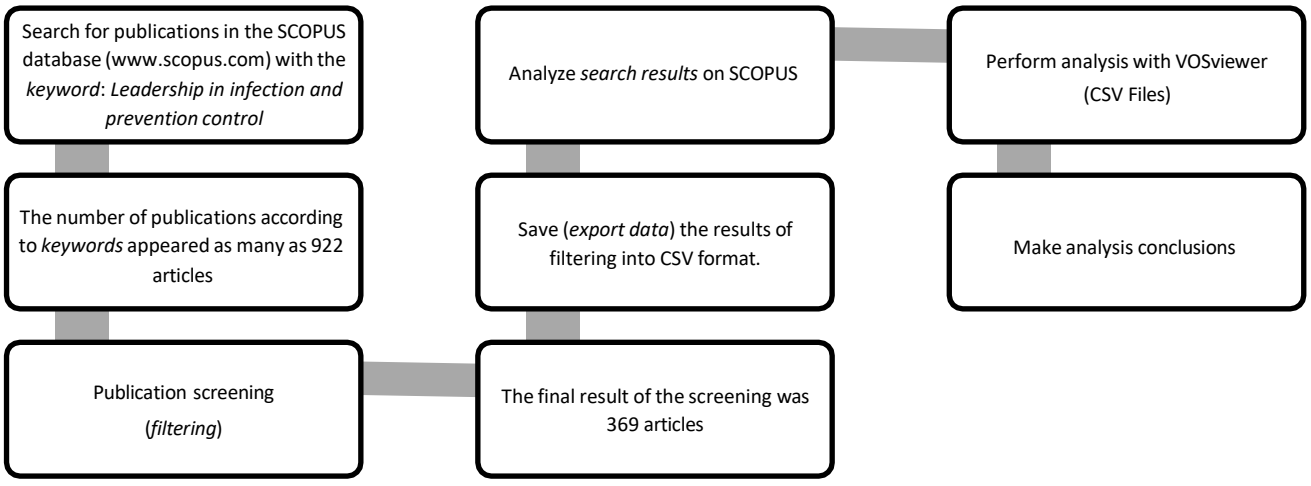

Figure 1 Research methods.

3. Results

3.1. Publication per year

The development of publications on leadership in infection and prevention control for the past 20 years is quite interesting. As shown Figure 2, the trend tends to increase from 2003 until it reached its highest point in 2020. Interestingly, when the world was in the COVID-19 pandemic in the range of 2019 to 2021, it did not cause publications to decline. On the contrary, the number of publications reached its highest point in 20 years, namely in 2020, then decreased from 2021 to 2022.

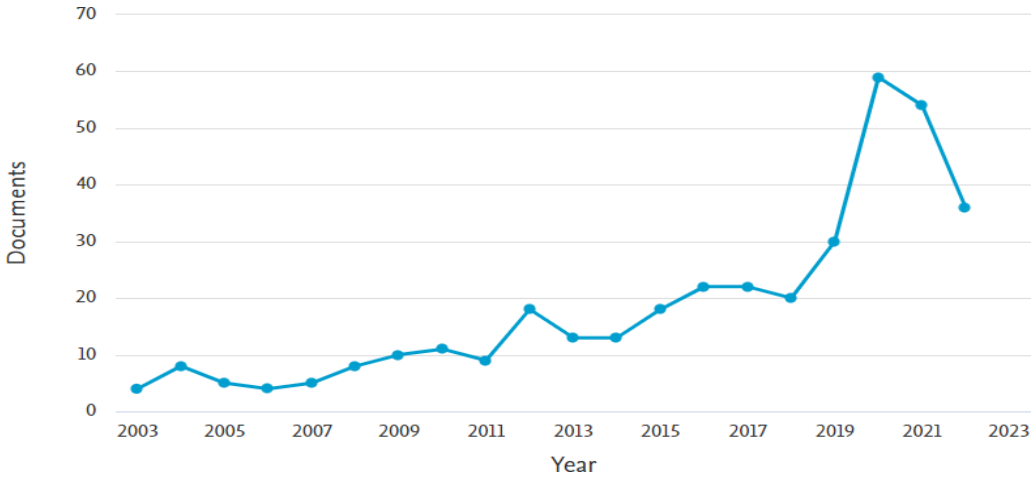

Figure 2 Annual publications. Source: Scopus Database.

3.2. Documents by affiliation

Based on Table 1, it can be seen that in 20 years, the most affiliations were by the Centers for Disease Control and Prevention with 20 articles, followed by Organization Mondiale de la Santé with 17 documents, then followed sequentially: by the University of Michigan Medical School 12 documents; VA Ann Arbor Healthcare System 12 documents; and in 10th place affiliation with the University of Washington with 8 documents.

Table 1 Top 10 affiliates related to the topic.

Affiliate	Number of Publications
Centers for Disease Control and Prevention	20
Organization Mondiale de la Santé	17
University of Michigan Medical School	12
VA Ann Arbor Healthcare System	12
Harvard Medical School	11
University of Toronto	11
University of California, San Francisco	11
University of Michigan, Ann Arbor	10
VA Medical Center	9
University of Washington	8

Source: Scopus Database

3.3. Documents by author

Based on Table 2, the most influential author is Saint, Sanjay K., a writer from the United States who has contributed to the publication of 489 documents and whose publications totaled 24,885. At the same time, the second position went to Krein, Sarah L., a writer from the United States with a total of 247 publications that have been written and 8,352 documents whose publications have been cited.

The table above shows that the countries that contributed the most publications on research topics were the United States with 192 documents, followed by the United Kingdom with 45 documents, and Australia in third place with 29 documents. The results shown in the table above are quite interesting. The country where research on the topic in the Asian continent was conducted was only China. Even then, in the top 10 countries, most publications related to the topic occupy the 7th position.

Table 2 Top 10 authors with the most publications related to the topic.

Author	Number of Publications
Saint, Sanjay K.	12
Krein, Sarah L.	9
Allegranzi, Benedetta	6
Pittet, Didier	6
Knobloch, Mary Jo	5
Safdar, Nasia	5
Tomczyk, Sara M.	4
Holmes, Alison Helen	4
Mody, Lona R.	4
Stone, Patricia W.	4

Source: Scopus Database

3.4. Documents by country

The Table 3 shows that the countries that contributed the most publications on research topics were the United States with 192 documents, followed by the United Kingdom with 45 documents, and Australia in third place with 29 documents. The results shown in the table above are quite interesting. The country where research on the topic in the Asian continent was conducted was only China. Even then, in the top 10 countries, most publications related to the topic occupy the 7th position.

Table 3 Top 10 countries with the most publications related to the topic.

Country	Number of Publications
United States	192
United Kingdom	45
Australia	29
Switzerland	26
Canada	22
South Africa	19
China	13
France	9
Germany	9
Tanzania	8

Source: Scopus Database

3.5. Documents per year by source

Table 4 Top 10 publications based on the most sources related to the topic.

Source	Number of Publications
American Journal Of Infection Control	34
International Journal Of Environmental Research And Public Health	11
Infection Control And Hospital Epidemiology	10
Clinical Infectious Diseases	8
Journal Of Hospital Infection	8
BMC Health Services Research	6
Globalization And Health	6
Journal Of Acquired Immune Deficiency Syndromes	6
Antimicrobial Resistance And Infection Control	5
BMJ Open	5

Source: Scopus Database

3.6. Co-occurrence of Keywords

Based on the analysis results with VOSviewer, the network visualization of co-occurrence based on keywords, as shown in Figure 3, has 52 items divided into 4 clusters marked with different colors. Cluster 1 consists of 19 items, such as the attitude of health personnel, hand hygiene, healthcare personnel, infection control, healthcare-associated infection, infection control, infection prevention, patient safety, and staff training. Cluster 2 consists of 16 items, such as COVID-19, healthcare management, healthcare organization, healthcare system, medical education, medical staff, and personal protective equipment. Cluster 3 consists of 10 items: behavior change, decision-making, education, health education, leadership, and

motivation. While cluster 4 consists of 7 items: healthcare planning, quality, organization, organization and management, program development, program evaluation, and public health service.

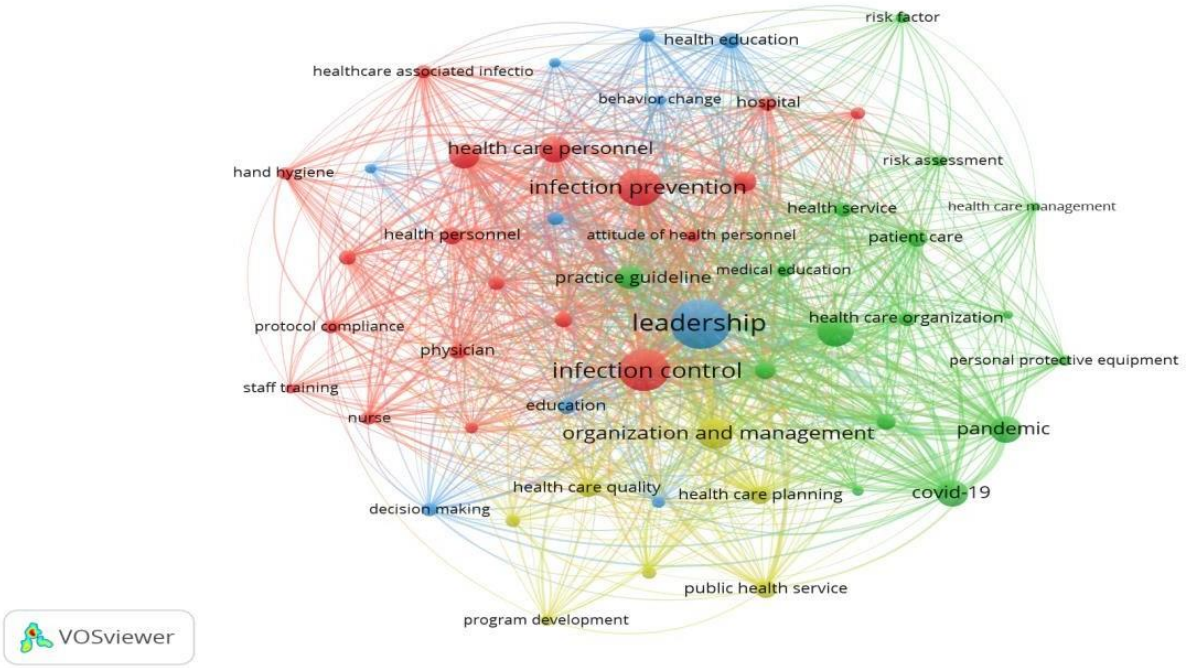

Figure 3 Network visualization of co-occurrence based on keywords.

3.7. Co-authorship

As shown in Figure 4, the most influential writer in 20 years on the research topic is Saint, Sanjay K., followed by Krein, Sarah L., and Allegranzi, Benedetta.

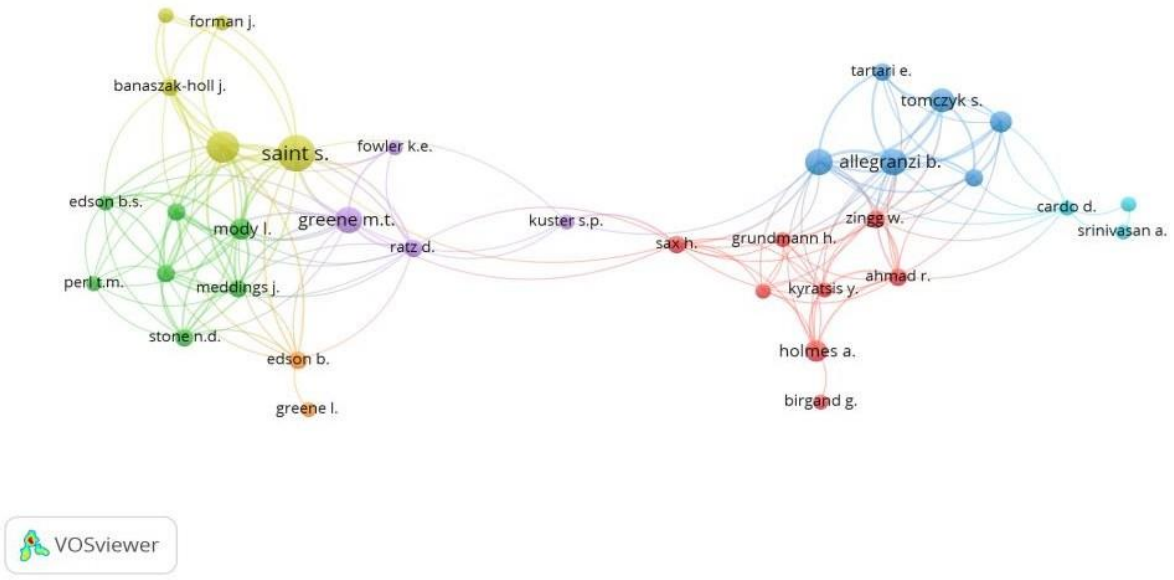

Figure 4 Co-authorship.

3.8. Co-occurrence of keyword: Leadership

Based on the results of the analysis with VOSviewer, the results of the network visualization of co-occurrence based on the keyword: leadership as shown in Figure 5, it is known that the keyword leadership has relations with quite some items such as infection control, organization, and management, procedure, practice guideline, healthcare personnel, patient safety, COVID-19, pandemic, personal protective equipment, healthcare planning, nursing education, behavior change, education, physician attitude, staff training, decision making, program development.

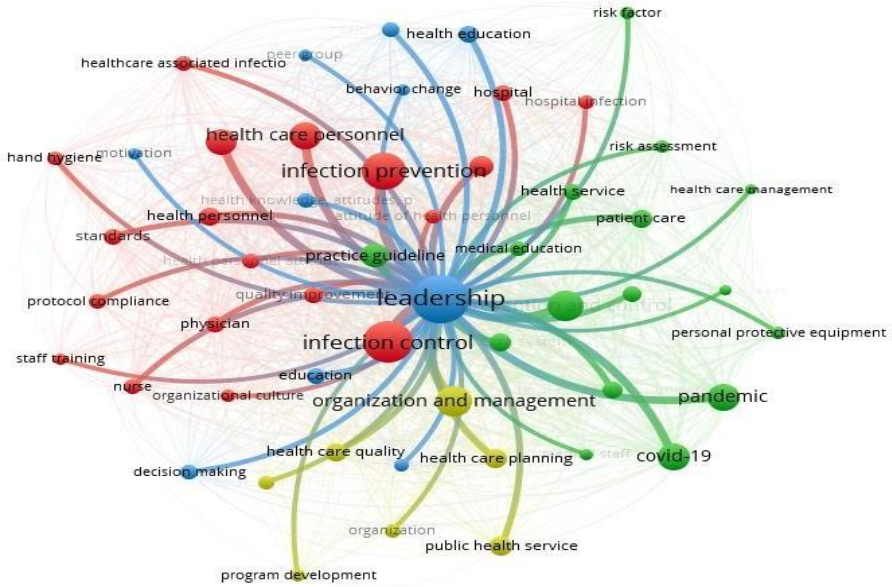

Figure 5 Network visualization of co-occurrence based on keyword: Leadership.

3.9. Co-occurrence of keyword: COVID-19

Based on the results of the analysis with VOSviewer, the results of the network visualization of co-occurrence based on the keyword: COVID-19, as shown in Figure 6, it is known that the keyword COVID-19 has quite some related items such as leadership, infection control, organization and management, practice guidelines, healthcare personnel, prevention and control, staff training, professional standard, nursing staff, public health service, protocol compliance, healthcare management, risk assessment, health education, organizational culture.

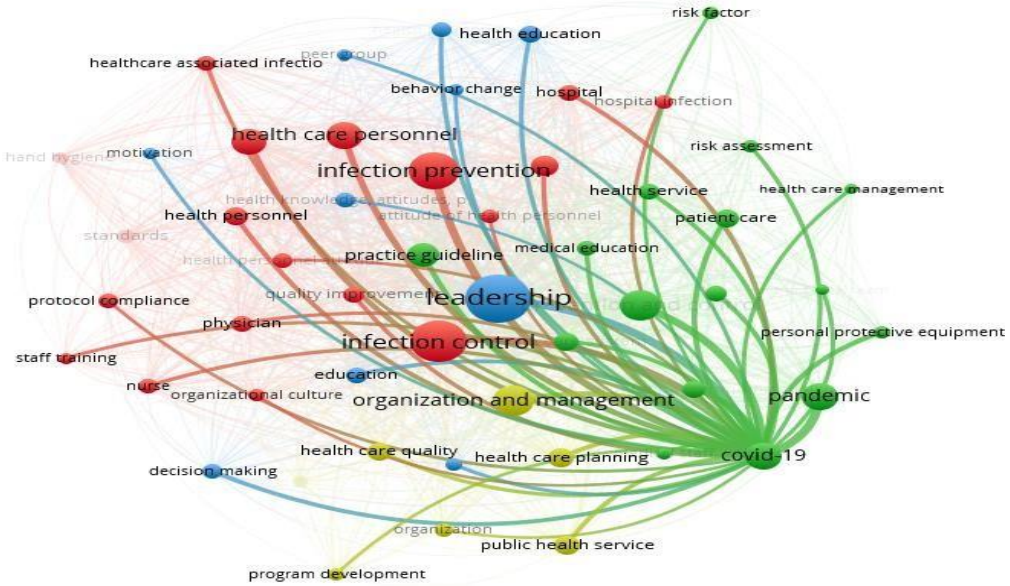

Figure 6 Network visualization of co-occurrence based on keyword: COVID-19.

3.10. Overlay visualization of leadership in infection prevention and control

According to the founders of the VOSviewer application (van Eck and Waltman 2023), overlay visualizations are used to show the progress of publications over time. In this study, the authors set the range of years in the overlay visualization from 2003 to 2022, as shown in Figure 7. A circle with a darker color (blue) indicates the year of publication is older, while on the contrary, a circle with a lighter color (yellow) indicates the year of publication is newer. For example, the author displays publications about leadership in infection prevention and control as shown in Figure 7, which shows that publications about leadership and infection control are marked with a green circle, which means the publications were made around 2015 to 2020 and interestingly the publications on this topic are networked with the topic of the publication, both with publications in earlier

or later years. This shows that publications about leadership in infection prevention and control are still quite interesting to be explored further.

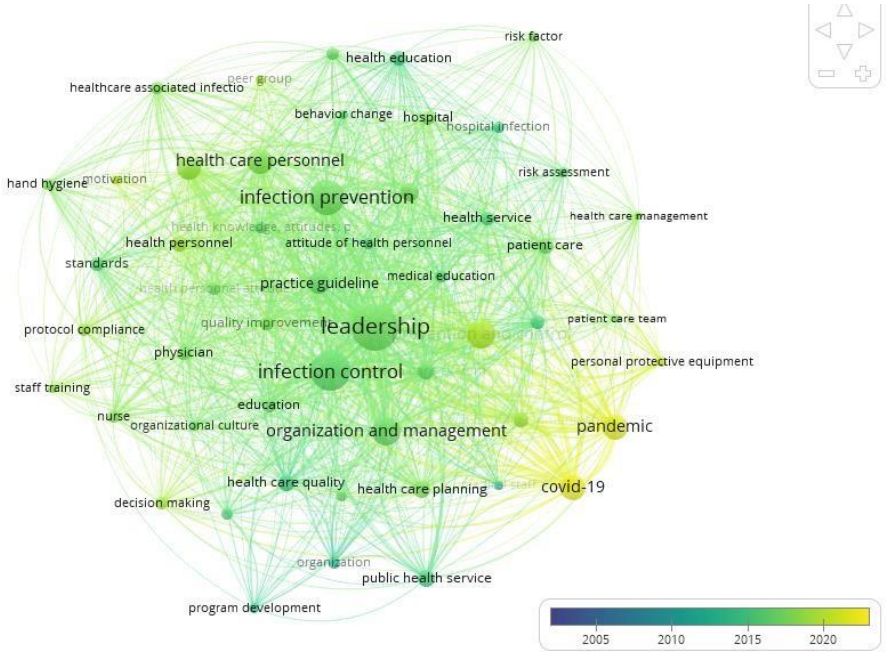

Figure 7 Overlay visualization of leadership in infection prevention and control publications 2003-2022.

3.11. Item density visualization of leadership in infection prevention and control

Figures 8 and 9 are density visualizations used to show an overview of the main items and clusters on the research topic. According to (van Eck & Waltman, 2010), each point on the item density has a color that indicates the item density at that point. By default, colors range from blue to green to yellow; the greater the number of items around a point and the higher the weight of the surrounding items, the closer the color of the dot is too yellow. Conversely, the smaller the number of items around a point and the lower the weight of the items around it, the closer the point's color is to blue, as shown in Figure 8.

Cluster density is similar to item density except that item density is shown separately for each item cluster. In cluster density, the color of a point in the visualization is obtained by mixing different cluster colors. The weight assigned to a particular cluster color is determined by the number of items belonging to that cluster around that point, as shown in Figure 9. Each point on the map has a color that depends on the density of items at that point. The density view is very useful for getting an idea of the general structure of the map and for drawing attention to the most important areas of the map. Figure 9 shows the dominant clusters related to transformational leadership clusters, such as leadership, infection control, infection prevention, organization and management, and healthcare personnel.

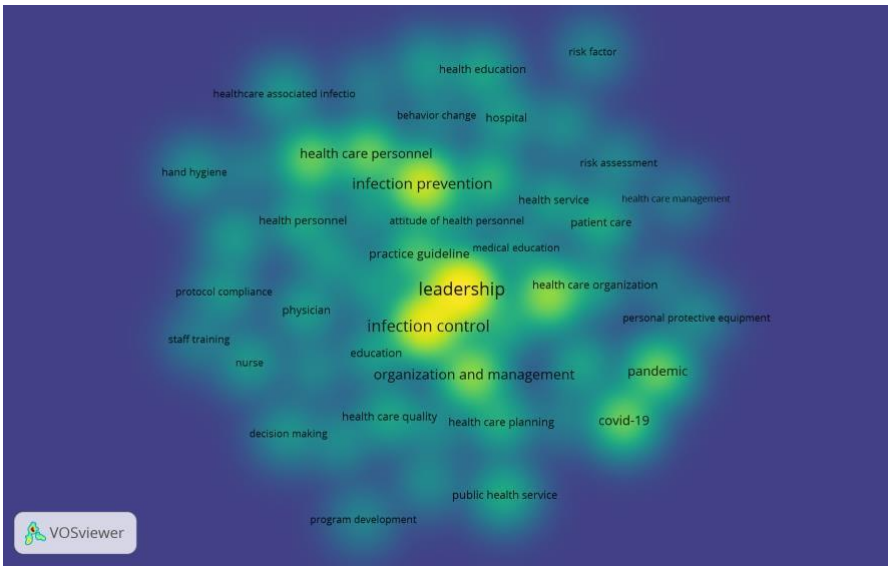

Figure 8 Item Density visualization of leadership in infection prevention and control publications 2003-2022.

3.12. Cluster density visualization of leadership in infection prevention and control

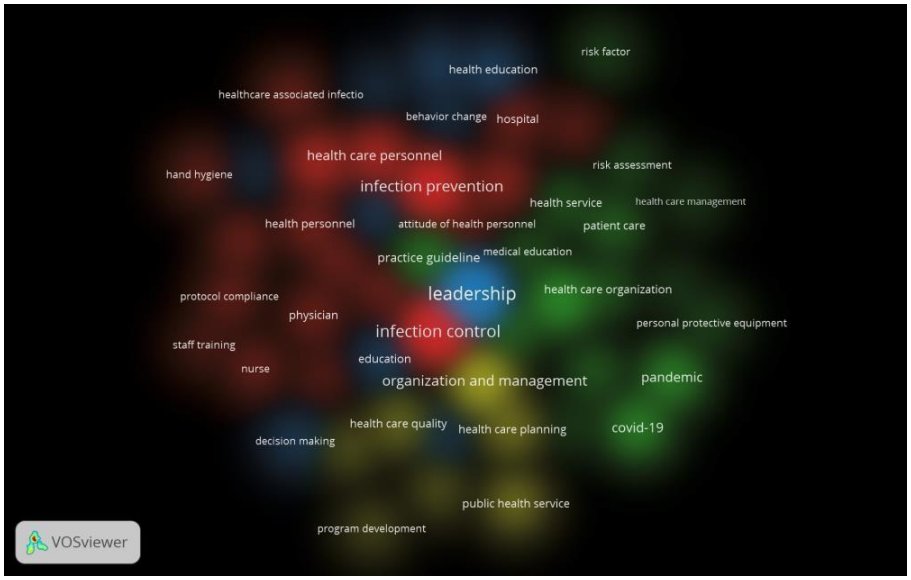

Figure 9 Cluster Density visualization of leadership in infection prevention and control publications 2003-2022.

Leaders have an important role in terms of infection prevention and control efforts through the organization that is responsible for the implementation of infection prevention and control. This is to the results of research conducted by (McAlearney et al 2013), which concluded that, in general, the success and sustainability of HAIs prevention are determined by the role of leadership. The results of VOSviewer's analysis in this study also reinforce this opinion, as seen from the results of the co-occurrence of keywords: leadership is connected with quite some items, ranging from infection control, healthcare personnel, behavior change, healthcare planning, education, staff training to the COVID-19 pandemic which occurred within 3 years. Research conducted by (Aagaard and Earnest 2021) supports this; namely, the role of a leader is important and very much needed in terms of handling the COVID-19 pandemic through effective decision-making and leadership communication.

Leaders are expected to be able to make changes or create a work culture in healthcare facilities that are oriented toward patient safety oriented. This is to the results of research by (Ginsburg et al 2010), which says that leadership support is very important in terms of services that can prioritize the realization of patient safety. The results of VOSviewer's analysis in this study also support the results where patient safety items are linked to leadership, infection control, healthcare personnel, and staff training. More details can be seen in Figure 10.

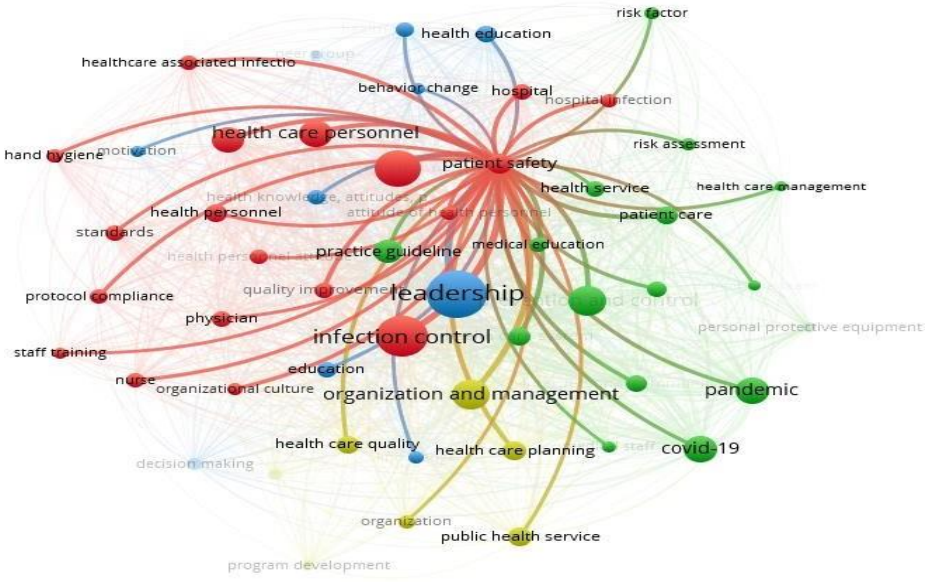

Figure 10 Network visualization of co-occurrence based on keyword: patient safety.

The COVID-19 pandemic requires health service facilities to make changes, especially in terms of changes in the behavior of health workers in providing health services, so that they comply with the principles of infection prevention and control to

realize the achievement of patient safety and the health workers themselves. This is to the results of the VOSviewer analysis, which shows that behavior change has a relationship with quite some items, as shown in Figure 11, and the connected items are interesting enough to be used as further research topics that can be related to leadership or infection control/ infection prevention.

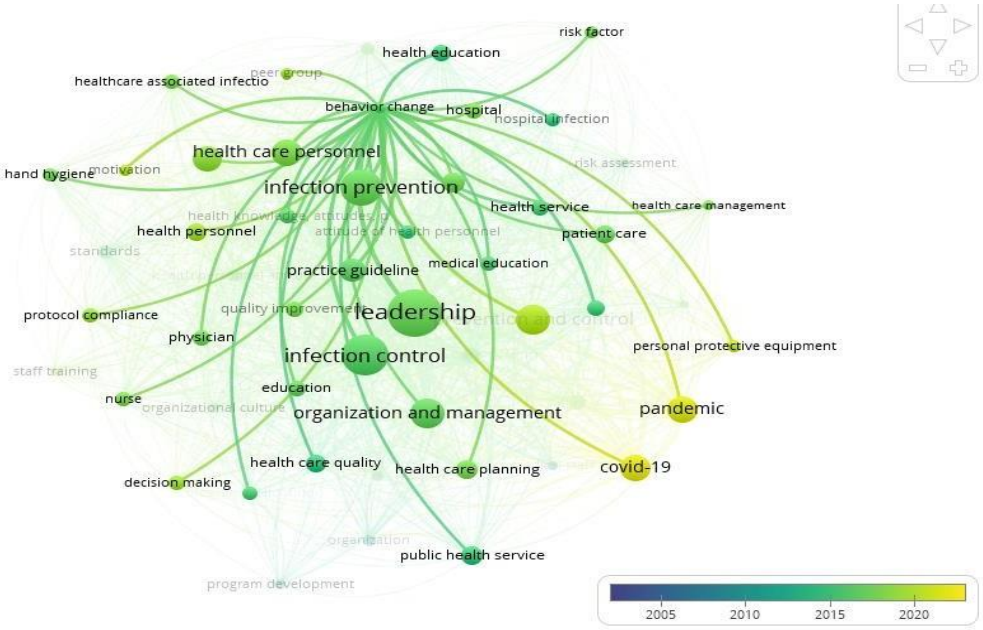

Figure 11 Overlay visualization of co-occurrence based on keyword: behavior change.

The bibliometric analysis in this study has practical and academic implications that are useful for future research. The results of this study show that the topics discussed have shown an increasing trend for 20 years, and interestingly the topics in this study reached their highest point during the COVID-19 pandemic, namely in 2020. Future research can examine topics with quite a lot of choices, not only the link between leadership and infection prevention but can also relate leadership to other topics, as shown in Figure 12.

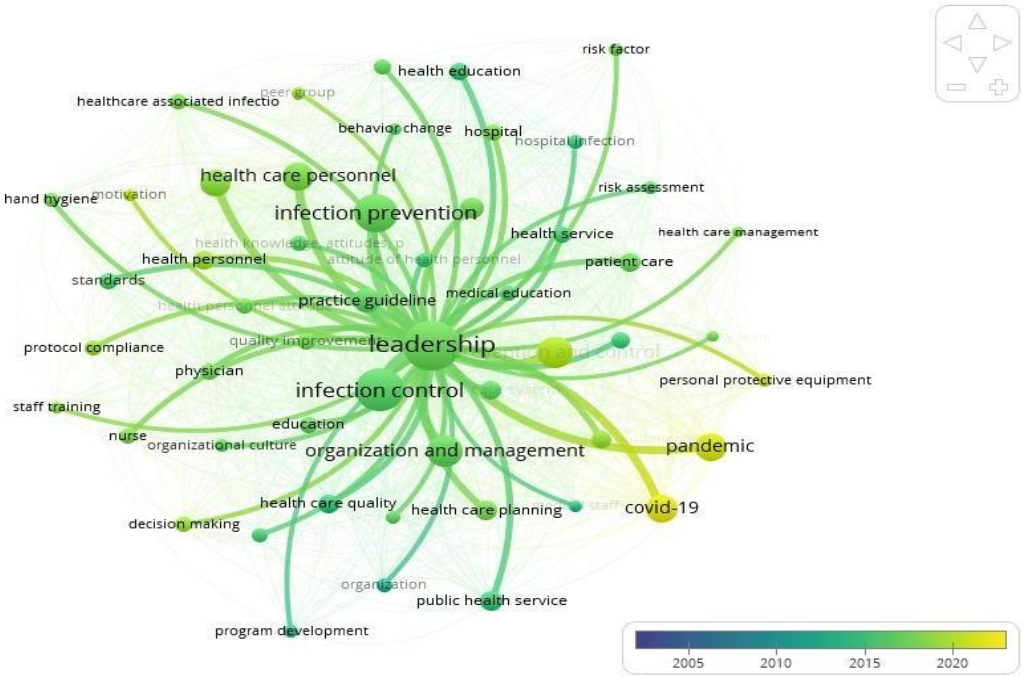

Figure 12 Overlay visualization of co-occurrence based on keyword: leadership.

4. Discussion

Research on leaders in infection prevention and control in healthcare is still a topic of interest. This can be seen from developments over the past 20 years; the number of publications on this topic has continued to increase. Based on this study,

the existence of the COVID-19 pandemic did not cause publications on the topic to decrease. On the contrary, it reached its highest point in the 2003-2022, namely in 2020. This was due to the existence of the COVID-19 pandemic in the past 3 years, which requires health service facilities, especially units responsible for infection prevention and control, to make changes ranging from regulations and procedures to increasing employee compliance in terms of infection prevention and control (Crain et al 2021).

Leaders have an important role in terms of infection prevention and control efforts through the organization that is responsible for the implementation of infection prevention and control. This is to the results of research conducted by (McAlearney et al 2013), which concluded that, in general, the success and sustainability of HAIs prevention are determined by the leadership role. The results of VOSviewer's analysis in this study also reinforce this opinion, as seen from the results of the co-occurrence of keywords: leadership is connected with quite some items, ranging from infection control, healthcare personnel, behavior change, healthcare planning, education, staff training to the COVID-19 pandemic which occurred within 3 years. Research conducted by (Aagaard and Earnest 2021) supports this; namely, the role of a leader is important and very much needed in handling the COVID-19 pandemic through effective decision-making and leadership communication.

Leaders are expected to be able to make changes or create a work culture in healthcare facilities that are oriented towards. This is to the results of research by (Ginsburg et al 2010), which says that leadership support is very important in terms of services that can prioritize the realization of patient safety. The results of VOSviewer's analysis in this study also support the results, where patient safety items are linked to leadership, infection control, healthcare personnel, and staff training. More details can be seen in Figure 10.

The COVID-19 pandemic requires health service facilities to make changes, especially in terms of changes in the behavior of health workers in providing health services, so that they comply with the principles of infection prevention and control to realize the achievement of patient safety and the health workers themselves. This is to the results of the VOSviewer analysis, which shows that behavior change has a relationship with quite some items, as shown in Figure 11, and the connected items are interesting enough to be used as further research topics that can be related to leadership or infection control/ infection prevention.

5. Conclusion

Research on leaders in infection prevention and control in healthcare is still a topic of interest. This can be seen from developments over the past 20 years; the number of publications on this topic has continued to increase. Based on this study, it can be seen that the COVID-19 pandemic did not cause publications on the topic to decrease; on the contrary, it reached its highest point in the 2003-2022 period, namely in 2020. This was due to the COVID-19 pandemic in the past 3 years, which requires health service facilities, especially units responsible for infection prevention and control, to make changes ranging from regulations and procedures to increasing employee compliance in terms of infection prevention and control.

5.1. Limitations

The limitation of this study is that the analysis was carried out only using bibliometric analysis from one database, namely SCOPUS. Apart from SCOPUS, there are other citations and abstract indexing databases, such as Microsoft Academic, Dimensions, Web of Science, PubMed, Crossref, Europe PMC, and others. Each of these databases has advantages and disadvantages, so it will be more interesting and add to the results of a more comprehensive analysis of additions or comparisons between several databases when carrying out a bibliometric analysis.

5.2. Implications for future research

The bibliometric analysis in this study has practical and academic implications that are useful for future research. The results of this study show that the topics discussed have shown an increasing trend for 20 years, and interestingly the topics in this study reached their highest point during the COVID-19 pandemic, namely in 2020. Future research can examine topics with quite a lot of choices, not only the link between leadership and infection prevention but can also relate leadership to other topics, as shown in Figure 12.

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

Funding

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References

Aagaard EM, Earnest M (2021) Educational leadership in the time of a pandemic: Lessons from two institutions. FASEB BioAdvances 3(3):182–188. DOI: 10.1096/fba.2020-00113

Agreli HF, Murphy M, Creedon S, Ni Bhuachalla C, O'Brien D, Gould D, Savage E, Barry F, Drennan J, Smiddy MP, Condell S, Horgan S, Murphy S, Wills T, Burton A, Hegarty J (2019) Patient involvement in the implementation of infection prevention and control guidelines and associated interventions: A scoping review. BMJ Open 9(3):1–11. DOI: 10.1136/bmjopen-2018-025824

Al-Tawfiq, JA, Tambyah, PA (2014) Healthcare-associated infections (HAIs) perspective. Journal of Infection and Public Health 7(4):339–344. DOI: 10.1016/j.jiph.2014.04.003

Alboksmaty A, Kumar S, Parekh R, Aylin, P (2021) Management and patient safety of complex elderly patients in primary care during the COVID-19 pandemic in the UK-Qualitative assessment. PLoS ONE 16(3):1–17. DOI: 10.1371/journal.pone.0248387

Alhumaid S, Al Mutair A, Al Alawi Z, Alsuliman M, Ahmed GY, Rabaan AA, Al-Tawfiq JA, Al-Omari A (2021) Knowledge of infection prevention and control among healthcare workers and factors influencing compliance: a systematic review. Antimicrobial Resistance and Infection Control 10(1):1–32. DOI: 10.1186/s13756-021-00957-0

Allen M, Hall L, Halton K, Graves N (2018) Improving hospital environmental hygiene with the use of a targeted multi-modal bundle strategy. Infection, Disease, and Health 23(2):107–113. DOI: 10.1016/j.idh.2018.01.003

Ashinyo ME, Dubik SD, Duti V, Amegah KE, Ashinyo A, Asare BA, Ackon AA, Akoriyea SK, Kuma-Aboagye P (2021) Infection prevention and control compliance among exposed healthcare workers in COVID-19 treatment centers in Ghana: A descriptive cross-sectional study. PLoS ONE 16(3):1–13. DOI: 10.1371/journal.pone.0248282

Asmara A, Hariyati RTS, Handiyani H, Avia I (2019) Analysis of Infection Prevention Control Nurse performance: A descriptive study. Enfermeria Clinica 29(2):36–40. DOI: 10.1016/j.enfcli.2019.04.006

Baker GR, Denis JL (2011) Medical leadership in healthcare systems: From professional authority to organizational leadership. Public Money and Management 31(5):355–362. DOI: 10.1080/09540962.2011.598349

Bayleyegn B, Mehari A, Damtie D, Negash M (2021) Knowledge, attitude, and practice on hospital-acquired infection prevention and associated factors among healthcare workers at the university of Gondar Comprehensive specialized hospital, northwest Ethiopia. Infection and Drug Resistance 14:259–266. DOI: 10.2147/IDR.S290992

Bessesen MT, Rattigan S, Frederick J, Cummings DAT, Gaydos CA, Gibert CL, Gorse GJ, Nyquist AC, Price CS, Reich NG, Simberkoff MS, Brown AC, Radonovich Jr LJ, Perl TM, Rodriguez-Barradas MC (2021) Outpatient healthcare personnel knowledge and attitudes towards infection prevention measures for protection from respiratory infections. American Journal of Infection Control 49(11):1369–1375. DOI: 10.1016/j.ajic.2021.06.011

Castro-Sánchez E, Holmes AH (2015) Impact of organizations on healthcare-associated infections. Journal of Hospital Infection 89(4):346–350. DOI: 10.1016/j.jhin.2015.01.012

Choi UY, Kwon YM, Kang HJ, Song JH, Lee HY, Kim MS, Kahm SH, Kwon JY, Kim SH, Lee SH, Choi JH, Lee J (2021) Surveillance of the infection prevention and control practices of healthcare workers by an infection control surveillance-working group and a team of infection control coordinators during the COVID-19 pandemic. Journal of Infection and Public Health 14(4):454–460. DOI: 10.1016/j.jiph.2021.01.012

Christenson M, Hitt JA, Abbott G, Septimus EJ, Iversen N (2006) Improving patient safety: Resource availability and application for reducing the incidence of healthcare-associated infections. Infection Control and Hospital Epidemiology 27(3):245–251. DOI: 10.1086/500370

Crain MA, Bush AL, Haynga H, Boyle A, Unger M, Ellison M, Ellison P (2021) Healthcare leadership in the COVID-19 pandemic: From innovative preparation to evolutionary transformation. Journal of Healthcare Leadership 13(5):199–207. DOI: 10.2147/JHL.S319829

Curryer C, Russo PL, Kiernan M, Wares KD Sc M, Smith K, Cert G, Mitchell BG (2020) Environmental hygiene, knowledge and cleaning practice: a phenomenological study of nurses and midwives during COVID-19. American Journal of Infection Control 49(2021):1123−1128. DOI: 10.1016/j.ajic.2021.04.080

Dietz L, Horve PF, Coil DA, Fretz M, Eisen JA, Van Den Wymelenberg K (2020) 2019 novel coronavirus (COVID-19) pandemic: built environment considerations to reduce transmission. mSystems 5:e00245-20. DOI: 10.1128/mSystems.00245-20

Doll M, Stevens M, Bearman G (2018) Environmental cleaning and disinfection of patient areas. International Journal of Infectious Diseases 67:52–57. DOI: 10.1016/j.ijid.2017.10.014

Donati D, Miccoli GA, Cianfrocca C, Di Stasio E, De Marinis MG, Tartaglini D (2020) Effectiveness of implementing link nurses and audits and feedback to improve nurses' compliance with standard precautions: A cluster randomized controlled trial. American Journal of Infection Control 48(10):1204–1210. DOI: 10.1016/j.ajic.2020.01.017

Geberemariyam BS, Donka GM, Wordofa B (2018) Assessment of knowledge and practices of healthcare workers towards infection prevention and associated factors in healthcare facilities of West Arsi District, Southeast Ethiopia: A facility-based cross-sectional study. Archives of Public Health 76(1):1–11. DOI: 10.1186/s13690-018-0314-0

Ginsburg LR, Chuang YT, Blair Berta W, Norton PG Ng P, Tregunno D, Richardson J (2010) The relationship between organizational leadership for safety and learning from patient safety events. Health Services Research 45(3):607–632. DOI: 10.1111/j.1475-6773.2010.01102.x

Graham RNJ, Woodhead T (2021) Leadership for continuous improvement in healthcare during the time of COVID-19. Clinical Radiology 76(1):67–72. DOI: 10.1016/j.crad.2020.08.008

Griffiths P, Renz A, Hughes J, Rafferty AM (2009) Impact of organization and management factors on infection control in hospitals: a scoping review. Journal of Hospital Infection 73(1):1–14. DOI: 10.1016/j.jhin.2009.05.003

Hall L, Farrington A, Mitchell BG, Barnett AG, Halton K, Allen M, Page K, Gardner A, Havers S, Bailey E, Dancer SJ, Riley TV, Gericke CA, Paterson DL, Graves N (2016) Researching effective approaches to cleaning in hospitals: Protocol of the REACH study, a multi-site stepped-wedge randomized trial. Implementation Science 11(1):1–10. DOI: 10.1186/s13012-016-0406-6

Hall L, White NM, Allen M, Farrington A, Mitchell BG, Page K, Halton K, Riley TV, Gericke CA, Graves N, Gardner A (2020) Effectiveness of a structured, framework-based approach to implementation: The Researching Effective Approaches to Cleaning in Hospitals (REACH) Trial. Antimicrobial Resistance and Infection Control 9(1):1–10. DOI: 10.1186/s13756-020-0694-0

Haque M, McKimm, J, Sartelli M, Dhingra S, Labricciosa FM, Islam S, Jahan D, Nusrat T, Chowdhury TS, Coccolini F, Iskandar K, Catena F, Charan J (2020) Strategies to prevent healthcare-associated infections: A narrative overview. Risk Management and Healthcare Policy 13: 1765–1780. DOI: 10.2147/RMHP.S269315

Hessels AJ, Genovese-Schek V, Agarwal M, Wurmser T, Larson EL (2016) Relationship between patient safety climate and adherence to standard precautions. American Journal of Infection Control 44(10):1128–1132. DOI: 10.1016/j.ajic.2016.03.060

Khan HA, Baig FK, Mehboob R (2017) Nosocomial infections: Epidemiology, prevention, control, and surveillance. Asian Pacific Journal of Tropical Biomedicine 7(5):478–482. DOI: 10.1016/j.apjtb.2017.01.019

Knobloch MJ, Chewning B, Musuuza J, Rees S, Green C, Patterson E, Safdar N (2018) Leadership rounds to reduce healthcare–associated infections. American Journal of Infection Control 46(3):303–310. DOI: 10.1016/j.ajic.2017.08.045

Knobloch MJ, Thomas KV, Musuuza J, Safdar N (2019) Exploring leadership within a systems approach to reduce healthcare–associated infections: A scoping review of one work system model. American Journal of Infection Control 47(6):633–637. DOI: 10.1016/j.ajic.2018.12.017

Kumar RDC, Khiljee N (2016) Healthcare leadership. Anesthesia and Intensive Care Medicine 17(1):63–65. DOI: 10.1016/j.mpaic.2015.10.012

Leach L, Hastings B, Schwarz G, Watson B, Bouckenooghe D, Seoane L, Hewett D (2021) Distributed leadership in healthcare: leadership dyads and the promise of improved hospital outcomes. Leadership in Health Services 34(4):353–374. DOI: 10.1108/LHS-03-2021-0011

Matlow AG, Wray R, Richardson SE (2012) Attitudes and beliefs, not just knowledge, influence the effectiveness of environmental cleaning by environmental service workers. American Journal of Infection Control 40 (3):260–262. DOI: 10.1016/j.ajic.2011.02.02

McAlearney AS, Hefner J, Robbins J, Garman AN (2013) The role of leadership in eliminating healthcare-associated infections: A qualitative study of eight hospitals. In Leading in Health Care Organizations: Improving Safety, Satisfaction and Financial Performance 14:69-94. DOI: 10.1108/s1474-8231(2013)0000014008

Parmeggiani C, Abbate R, Marinelli P, Angelillo IF (2010) Healthcare workers and healthcare-associated infections: Knowledge, attitudes, and behavior in emergency departments in Italy. BMC Infectious Diseases 10. DOI: 10.1186/1471-2334-10-35

Patel H, Virapongse A, Baduashvili A, Devitt J, Barr R, Bookman K (2021) Implementing a COVID-19 Discharge Pathway to Improve Patient Safety. American Journal of Medical Quality: The Official Journal of the American College of Medical Quality 36(2):84–89. DOI: 10.1097/01.JMQ.0000735436.50361.79

Peter D, Meng M, Kugler C, Mattner F (2018) Strategies to promote infection prevention and control in acute care hospitals with the help of infection control link nurses: A systematic literature review. American Journal of Infection Control 46(2):207–216. DOI: 10.1016/j.ajic.2017.07.031

Peters A, Schmid MN, Parneix P, Lebowitz D, de Kraker M, Sauser J, Zingg W, Pittet D (2022) Impact of environmental hygiene interventions on healthcare-associated infections and patient colonization: a systematic review. Antimicrobial Resistance and Infection Control 11(1):1–25. DOI: 10.1186/s13756-022-01075-1

Quinn MM, Henneberger PK, Braun B, Delclos GL, Fagan K, Huang V, Knaack JLS, Kusek L, Lee SJ, Le Moual N, Maher KAE, McCrone SH, Mitchell AH, Pechter E, Rosenman K, Sehulster L, Stephens AC, Wilburn S, Zock JP (2015) Cleaning and disinfecting environmental surfaces in healthcare: Towards an integrated framework for infection and occupational illness prevention. American Journal of Infection Control 43(5):424–434. DOI: 10.1016/j.ajic.2015.01.029

Saint S, Kowalski CP, Banaszak-Holl J, Forman J, Damschroder L, Krein SL (2010) The Importance of Leadership in Preventing Healthcare-Associated Infection: Results of a Multisite Qualitative Study. Infection Control & Hospital Epidemiology 31(9):901–907. DOI: 10.1086/655459

Sakr F, Haddad C, Zeenny RM, Sacre H, Akel M, Iskandar K, Hajj A, Salameh P (2022) Work Ethics and Ethical Attitudes among Healthcare Professionals: The Role of Leadership Skills in Determining Ethics Construct and Professional Behaviors. Healthcare (Switzerland) 10(8). DOI: 10.3390/healthcare10081399

van Eck NJ, Waltman L (2010) Survey software: VOSviewer, a computer program for bibliometric mapping. Scientometrics 84(2):523–538. DOI: 10.1007/s11192-009-0146-3

van Eck NJ, Waltman L (2023) VOSviewer manual. In Manual for VOSviewer version 1.6.19 (January Issue). The Center for Science and Technology Studies (CWTS), Leiden University. Avaliable in: https://www.vosviewer.com/getting-started Accessed on: January 4, 2023.

Voidazan S, Albu S, Toth R, Grigorescu B, Rachita A, Moldovan I (2020) Healthcare-associated infections—a new pathology in medical practice? International Journal of Environmental Research and Public Health 17(3). DOI: 10.3390/ijerph17030760

Ward D (2016) The role of the infection prevention and control link nurse. Primary healthcare 26(5):28–31. DOI: 10.7748/phc.26.5.28.s29

Weber DJ, Anderson D, Rutala WA (2013) The role of the surface environment in healthcare-associated infections. Current Opinion in Infectious Diseases 26(4):338–344. DOI: 10.1097/QCO.0b013e3283630f04

Wong ELY, Ho KF, Dong D, Cheung AWL, Yau PSY, Chan EYY, Yeoh EK, Chien WT, Chen FY, Poon S, Zhang Q, Wong, SYS (2021) Compliance with standard precautions and its relationship with views on infection control and prevention policies among healthcare workers during the COVID-19 pandemic. International Journal of Environmental Research and Public Health 18(7). DOI: 10.3390/ijerph18073420

Yen MY, Schwartz J, King CC, Lee CM, Hsueh PR (2020) Recommendations for protecting against and mitigating the COVID-19 pandemic in long-term care facilities. Journal of Microbiology, Immunology and Infection 53(3):447–453. DOI: 10.1016/j.jmii.2020.04.003

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Analyzing the misleading information on Covid-19 using MBCFWS4

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Abstract The COVID-19 pandemic had a major effect on almost every area of human lives in the majority of the world's countries. Misinformation spreads quickly in the initial phases of the COVID-19 pandemic in different forms, such as fear, distortion, contraindication assumption, and others. False and misleading advertisements harm millions of individuals. In recent research, there are more advanced techniques have been used to address the misinformation about the COVID-19 pandemic. But they are self-reported and probabilistic data during the lockdown period. So, it was difficult to find the respondents' perceptions based on sharing the COVID-19 misinformation. This proposed work analyzed and filtered some optimized factors to analyze the misinformation such as fake reports, fake remedies, conspiracy, susceptibility, vaccine rumors, social media, vitamin D prevents corona, political corona, socio-Economic, and more side effects after getting vaccinated. Collaborative filtering (CF) is the most efficient recommender system, and it is extensively utilized by a broad range of research institutions and enterprises, as well as being used in practice. It consists of two types of CF namely Memory-based CF and Model-based CF. In this work, Memory-based CF recommendation algorithm is combined with a similarity measure called MBCFWS4 to analyze the similarity measure between the factors to conclude the most impact factor. The Primary and secondary dataset helps to identify the respondents' perception based on the COVID-19 misinformation. The efficiency comparison of the proposed work is measured in terms of Precision, Recall & F-measure and found that this analysis using MBCFWS4 is outperforming well than the others as MBCFWS4 predicted accurately and revealed the conclusion based on the COVID-19 misinformation.

Keywords: corona virus, misinformation, memory-based CF, respondent’s perception, similarity measure, ten factors

1. Introduction

The COVID-19 pandemic is a significant public health issue, as well as an impact on the world's financial sector. Disease mitigation measures implemented in several places result in increased unemployment, significant income reductions, and interruptions in the transportation, service, and production industries. The majority of governments across the country tend to have underestimated the dangers of the rapid COVID-19 spread and have been primarily reactive in their disaster response (Pak et al 2020). Nowadays, several websites have published information on COVID-19 and offered their users various instructions. In this regard, social media technologies are establishing a viable stage for timely interaction about health to specific users while simultaneously establishing a hotspot of disinformation generation, development, and transmission.

It is possible that individuals may be perplexed and will not make the correct option regarding COVID. Misinformation is often disseminated in a “florid” atmosphere overloaded with information overload, functional illiteracy, and confirmation bias. Misinformation will spread more quickly and widely, especially during a pandemic, since the public's response to pandemics and important social events appears to be extremely susceptible to error. The public typically gathers several types of knowledge about potential upcoming threats, creating the potential for disinformation to spread. The probabilistic decision always ends with disaster in the environment, and the right individual decision helps to secure health.

But, most people make the wrong decision in pandemic situations right from the sharing of misinformation. No analysis helps to make the right decisions about COVID and the causes of sharing misinformation dealing with various defects related to economically. (Roozenbeek et al 2020) Specific disinformation claims, when examined, are generally considered trustworthy by a significant portion of the population and constitute a serious public health concern. Importantly, this research shows a clear relationship, which has been repeated worldwide, between sensitivity to disinformation and vaccination reluctance and a lower probability of following public health advice. This study emphasized the essential part that scientists play as trusted and consistent information disseminators, as well as the possible relevance of strengthening capabilities in numeracy and logical reasoning to minimize exposure to misinformation.

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Elhadad et al (2020) addressed the issue of identifying false information about COVID-19. We present a methodology for detecting false information that uses information from the UNICEF, World Health Organization, and the United Nations, as well as epidemiological data gathered from various internet sites for fact-checking. Collecting information from credible resources must ensure its accuracy. The acquired ground-truth value was utilized to develop a recognition mechanism that employs machine learning to recognize false information in this study. (Al-Zaman 2021) To get well knowledge of the misinformation issues of the pandemic in India, researchers underlined a new paradigm in the country's communication organization, a deficit of digital literacy, insufficient anti-misinformation efforts, and the political situation.

The previous analysis is based on self-reported data from self-selected individuals, and the lockdown time was a limitation in gathering more representative data. It was challenging to locate individuals who wanted to take part in their research. Among all the others, the most successful technique for analyzing the effects of COVID is factor analysis, but there are no real factors to measure the pandemic effects, and there are no right decisions taken under the factor analysis. Our proposed work studied and analyzed the real-time factors that are collected to measure the COVID pandemic causes. The contribution of this proposed work is to overcome the decision-based problems of COVID-19 and conclude the most influencing factor based on COVID-19 using MBCFWS4.

The proposed work readies the primary source data, i.e., a structured questionnaire that was used to determine the individual responses toward the effects of COVID-19 misinformation. The secondary source data is also used and collected online. And more importantly, the proposed work considers several factors related to the COVID pandemic to analyze people's perceptions and reveal the right decision. This work used the (Ejegwa 2020) proposed work called a new similarity measure which is used to combine in memory-based collaborative filtering technique as MBCFWS4 to determine the similarity between proposed factors. Figure 1 represents the workflow diagram.

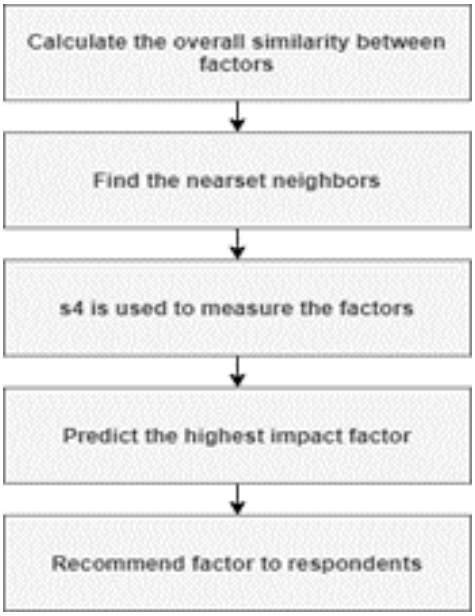

Figure 1 Flow diagram.

1.1. Literature survey

Peng (2018) presented a new Pythagorean Fuzzy distance and similarity metric. Some intriguing features of distance and similarity measurements were demonstrated. To demonstrate the availability of similarity metrics among (Pythagorean Fuzzy Set) PFS, several remarkable scenarios are provided.

Chen et al (2018) reviewed the conventional CF-based methods and approaches utilized in (Recommender System) RS and investigated several new hybrid CF-based recommendation systems and methods, comprising the most recent hybrid memory-based and model-based CF recommendation techniques. Finally, this workshop examined the possible influence that might enhance the RS as well as the future path. This paper proposed current hybrid CF-based recommendation approaches integrating social networks to tackle high dimensionality and data sparsity, as well as give a new point of view to increase RS performance.

Hatmal et al (2021) suggested that authorized COVID-19 vaccinations are safer, as well as being vaccinated makes individuals feel safer. Most of the adverse responses after vaccination are usually mild, representing that the innate immune system is boosting its resistance. In addition, machine learning techniques are developed to assess the intensity of side effects, and it was discovered that XGBoost, RF, and MLP offered excellent prediction accuracy in predicting the level of adverse effects depending upon the input data.

Roy and Ghosh (2020) processed multiple open-access datasets on US states to generate a unified database of probable pandemic spread variables. Then, use a variety of supervised machine learning methods to achieve an opinion and list the essential criteria. The analysis of regression is used to identify the important pre-lockdown variables that influence post-lockdown infection and death, influencing imminent lockdown policies.

Strength-opportunity (SO), weakness-threat (WT), strength-threat (ST), and weakness-opportunity (WO) methods for COVID-19 prevention and management were evaluated and developed by Wang and Wang (2020). This paper performed a thorough investigation and selected the most significant policies, and they are as follows: reconfiguring the emergency system (SO1), incorporating health emergency departments into universities and other institutions (WO2), modifying the financial structure and enhancing domestic and international connections (ST2), and improving public involvement in contributing to public health emergencies (WT1).

Almost 18 million tweets about coronavirus were gathered between March 1, 2020, and May 31, 2020, and were examined by Tariq Soomro et al (2020). This study examines the link concerning public attitude and the number of COVID-19 cases using VADER, a rule-based supervised machine learning model. This research also examines the frequency with which a nation is mentioned in tweets, as well as the increase in its daily sum of COVID-19 instances.

The macroeconomic impact of the COVID-19 pandemic on the UK and the government's response activities were assessed by comparing actual information and building regression models with STATA (Junlan and Chengke 2020). Before the pandemic, the British economy was in great condition. The emergence of COVID-19, on the other hand, has sent the British economy into a tailspin. The British government and the Bank of England have devised a lot of techniques to mitigate the pandemic's economic impact.

Ma et al (2020) analyzed the mental health level of the public, like anxiety, nervousness, fear, and panic. This work found that positive emotions stood at 14.64%, neutral emotion blog posts still accounted for 66.64%, and negative emotions accounted for 18.72%. In the negative segment, the general negative emotions accounted for 12.485%, the moderate negative emotions accounted for 4.9%, and the users who showed a high degree of negative emotions accounted for 0.455% and then roughly given the relevant strategies and suggestions for some groups which have intense negative emotions. The limitation is that we can't give them specific suggestions for different users for the time being, which needs further research in the future.

Vrindavanam et al (2021) analyzed cough audio recordings; they were able to discover COVID-19 patients without using any contact. The article presents three machine learning techniques for classification and finds the best classifier among these three models. This work used a way of picking features that depended on ranking different scores generated by feature selection techniques. The preliminary findings will be a part of a broader study to build appropriate interfaces since these systems can help frontline employees by reducing stress and offering an effective approach to handling healthcare professionals' time and resources.

A new prediction approach for a collaborative filtering recommender system was developed by Alhijawi et al (2021). This prediction system is made up of a unique adaptive predictive model known as inheritance-based prediction (INH-BP) and an appropriate heuristic search method. INH-BP allows the predictor to be tailored to the user's specific needs. It uses an optimization technique, including a genetic algorithm, to form a user interest print (UIP) matrix.

Ghazarian and Nematbakhsh (2015) resolved data sparsity problems to improve memory-based approaches for group recommendation systems. The suggested technique is built around a support vector machine learning algorithm that calculates similarities between objects. This method makes use of computed similarities and improves on simple memory-based strategies.

Bhalse and Thakur (2021) proposed a movie recommendation system with the primary goal of generating a suggested list using singular value decomposed cosine similarity and collaborative filtering. The framework using a factorization form that substantially decreases the number of parameters while maintaining a regulated complexity has been improved.

1.2. Objective

The justification of the work is analyzing misconceptions about the Coronavirus and determining the influential element. In this age of global connectivity, where one erroneous thought can travel immediately to too many sensitive ears, misinformation is a profoundly harmful force. The impacts of misinformation are especially important to comprehend in the setting of a pandemic when people require trustworthy details to make key decisions that influence their own and others' well-being. During the pandemic, health emergencies, and humanitarian crises, people experience emotional, social, political, and/or economic hardship as a result of incorrect and deceptive health-related information on social media, according to systematic research.

It also has an impact on the individual who is prepared to get a Covid19 vaccination. Furthermore, it is critical to study how disinformation affects different socio-demographic categories and if populations at high risk of having serious COVID-19 problems are more prone to misinformation. Taking these issues into account, the proposed work's purpose is to thoroughly examine the disinformation of covid19 and its sources. The objective of this study is to investigate the causes that are propagating misconceptions about Covid19 and its treatment, as well as side effects, based on people's opinions. After completing the examination, identify the most influential cause that is responsible for the widespread misunderstanding. It

assists individuals in making clear decisions and strengthens the mentality of those who are afraid about the Covid19 vaccinations and their treatment.

2. Materials and Methods

According to the factor-factor perception matrix, the memory-based CF recommendation system finds comparable links between variables and then recommends factors to active factors that have a high perception based on data obtained from respondents. In memory-based CF, the perception of factors from respondents is directly utilized to forecast which one has the highest value using the proposed calculation and find one factor among the COVID-19-based factors. There are two types of memory-based recommendation methods: misinformation factor-based CF Recommendation and affected Factor by misinformation-based CF Algorithm. The rationale of misinformation-based CF and affected by misinformation-based CF is presented in Figure 2.

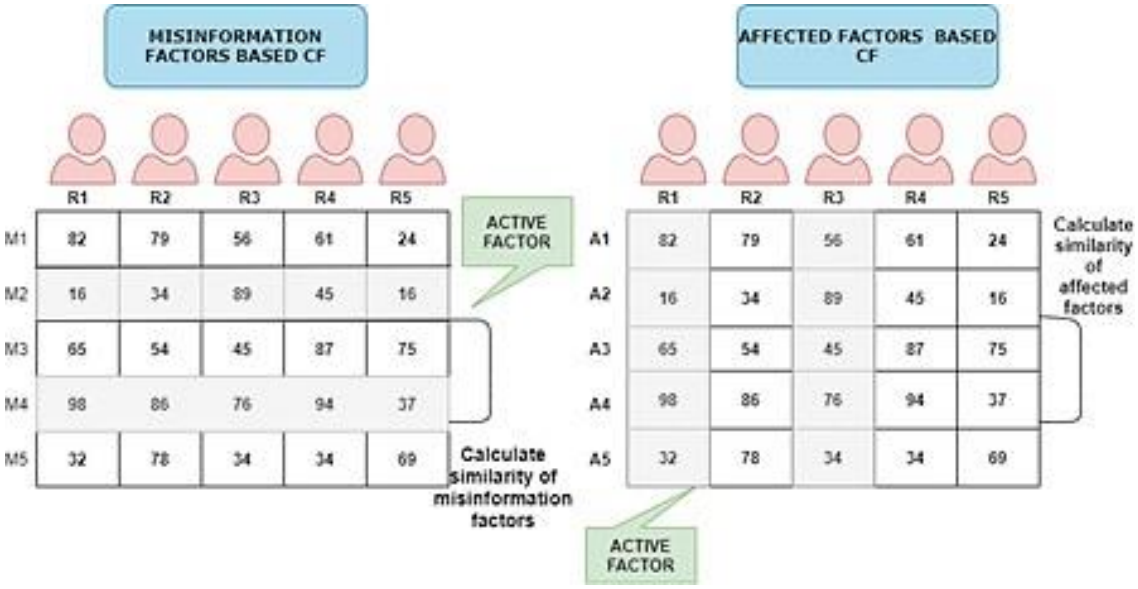

Figure 2 The rationale of misinformation-based CF and affected by misinformation-based CF.

Following Board 1 refers to the primary data based on the questionnaire type and contains 3 types of options. In this context, 100 respondents share their perceptions by choosing the options. Finally, this work calculates the primary data based on the respondents' count. It is represented in parenthesis near the option. For example, in the first question, 82 respondents have chosen option A, and 18 respondents have chosen option B.

Board 1 Primary data.

1)	Which spreads **fake reports** about corona?		
	A) Social media (0.82)	B) Video sites (0.18)	C) Search engines
2)	Which **fake remedy** is often recommended to treat corona?		
	A) (0.43) The keto diet can cure COVID-19	B) Vitamin D prevents corona (0.57)	C) Herbal remedies can help
3)	Who spreads the **conspiracy** information based on COVID-19?		
	A) (0.26) China Corona Conspiracy	B) Political Corona Conspiracy (0.72)	C) No idea
4)	Which type of **susceptibility** is caused fear in people?		
	A) Epidemic susceptibility (0.45)	B) Socio-Economic susceptibility (0.55)	C) Both A and B
5)	Which rumor spread against COVID **vaccination**?		
	A) food and drug allergies are carefully vaccinated (0.30)	B) More side effects after getting vaccinated (0.70)	C) Both A and B

Following Boards 2 and 3 refer to the secondary data based on the possibilities of respondent answers in percentage, and that is divided by the hundred and the resultant answer is taken as in the proposed analysis. For example, R1 is one of the respondents. He/she gave the perceptions based on the six affected factors. i.e., in Board 2, the first factor R1 gave their perception as 28%; after that, 28% is considered to be divided by hundred, that is 0.28. This type of data is retrieved from an online source (Nielsen et al 2021; Ilie et al 2020; Pummerer et al 2021; Augustine 2020).

Board 2 Secondary data for misinformation factors.

Sample number of Respondents	Fake reporting M1			Fake remedies M2			Conspiracy M3			Susceptibility M4			Vaccine rumors M5		
	Option %			Option %			Option %			Option %			Option %		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
R1	28	16	11	57	65	73.5	40	40	8	0.000	0.011	0.000	53	47	32
R2	35	24	23	67.7	65	47.4	6.4	6	5.75	0.099	0.000	0.249	68	38	62
R3	27	22	16	56.4	59.5	49.3	4.5	3.5	6.25	0.011	0.021	0.099	93	7	18
R4	30	21	16	50.1	60	46	6.2	5.2	7	0.130	0.249	0.390	82	80	20
R5	20	17	15	50	42.5	51	6	7	5	0.021	0.041	0.130	67	33	64

Board 3 Secondary data for affected factors by misinformation**.**

Sample number of Respondents	Social media A1			Vitamin D prevents corona A2			Political Corona Conspiracy A3			Socio-Economic susceptibility A4			More side effects after getting vaccinated A5		
	Option %			Option %			Option %			Option %			Option %		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
R1	26	21	16	62.5	81.5	60.6	3	7	4.75	0.153	0.390	0.525	36	95	5
R2	12	11	27	51.8	39	0	6.2	6.4	5.4	0.041	0.081	0.153	5	95	95.5
R3	27	20	13	68	19	18	5.8	4	5.8	0.178	0.525	0.666	4.5	45.7	41.3
R4	21	10	15	38	48	7	5.6	6.4	4	0.081	1.000	0.178	10.5	2.5	29.4
R5	35	21	27	25	18	9	6.4	7	6	1.000	0.666	1.000	44.3	6.3	11.1

The primary and secondary data are helping to identify the highest misinformation factor as well as to identify the affected factor by misinformation based on COVID-19 using MBCFWSM.

2.2. Factors description

2.2.1. Fake reporting

The fake reporting factor refers to news and messages that contain incorrect information or false report about the corona. The public is concerned about incorrect or misleading data regarding COVID-19 on social media such as Facebook, Google Search, YouTube, Twitter, and WhatsApp.

2.2.2. Fake remedies

The fake remedies factor denotes the wrongly spreading treatments of COVID-19 on any social media or any other platform.

2.2.3. Conspiracy

Conspiracy theories seek to explain the absolute causes of important social and political events and conditions by suggesting hidden conspiracies hatched by two or more influential actors. In the era of 2020, the Political and China-based corona conspiracy is trying to attempt confusion among the people.

2.2.4. Susceptibility

The susceptibility factor is being like to be influenced or harmed by COVID-19. Two types of Susceptibility are frequently explored in the corona mislead, like Socio-Economic susceptibility and epidemic susceptibility.

2.2.5. Vaccine rumors

Rumors and conspiracies can foster mistrust, contributing to vaccination hesitation, such as food and drug allergies, being carefully vaccinated, more side effects after getting vaccinated, etc.

2.3. Misinformation Factor-Based CF Recommendation Algorithm

2.3.1. Calculate the Similarity between Misinformation factors using cosine similarity

Cosine similarity is being used to assess responders' perceptions depending on the elements that may be represented as a vector of n-dimension, and the similarity of the components is determined by the angle of the respondents' perception vector. In general, the greater the similarity, the smaller the angle. The perceptions of the respondents are typically characterized as the perception vector $P_M\{P_{M_1}, P_{M_2}, \dots . P_{M_5}\}$. The similarity between the five misinformation factors is determined by comparing their perception vectors.

Cosine similarity is the traditional metric for calculating factor similarity. In cosine similarity, first the respondent's perception is gathered which represents the n-dimensional vector, and then the similarity among factors are calculated based on the angle of the factors perception vector. In general, the greater the similarity, the smaller the angle. This calculation used the primary data values for findings the similarity as well as considering the highest respondents count for calculating the similarity, such as 0.82, 0.57, 0.72, 0.55, and 0.70:

$$Sim_{A,B} = cos(A,B) = \frac{\sum_{i=1}^{n} A_i * B_i}{\sqrt{\sum_{i=1}^{n} A_i^2} * \sqrt{\sum_{i=1}^{n} B_i^2}} \text{ As instead of } Sim_{M_1,M_2,M_3,M_4,M_5} = cos(\vec{P}_{M_1}, \vec{P}_{M_2}, \vec{P}_{M_3}, \vec{P}_{M_4}, \vec{P}_{M_5})$$

$$= \frac{\vec{P}_{M_1} . \vec{P}_{M_2} . \vec{P}_{M_3} . \vec{P}_{M_4} . \vec{P}_{M_5}}{\| \vec{P}_{M_1} \|_2 * \| \vec{P}_{M_2} \|_2 * \| \vec{P}_{M_3} \|_2 * \| \vec{P}_{M_4} \|_2 * \| \vec{P}_{M_5} \|_2}$$

$$= \frac{\sum_{i=A_1 \, to \, 5 M_1 \, to \, 5}^{n} M_1 * M_2 * M_3 * M_4 * M_5}{\sqrt{\sum_{I \in A R1,2,\ldots n} P_{M_1}^2} \sqrt{\sum_{I \in A \, R1,2,\ldots n} P_{M_2}^2} \sqrt{\sum_{I \in A \, R1,2,\ldots n} P_{M_3}^2} \sqrt{\sum_{I \in A \, R1,2,\ldots n} P_{M_4}^2} \sqrt{\sum_{I \in A \, R1,2,\ldots n} P_{M_5}^2}} \quad (1)$$

Where $M_{1\,to\,5}$ represents the misinformation factors and $A_{1\,to\,5}$ denotes the affected factors by misinformation factors. Where $Sim_{M_1,M_2,M_3,M_4,M_5}$ represents the similarity between five misinformation factors, and $\vec{P}_{M_1} \ldots \vec{P}_{M_5}$ represents the perception vectors of F_1 toF_5 respectively. $\| \vec{P}_{M_1} \|_2 \, to \, \| \vec{P}_{M_5} \|_2$ represents 2-norm of F_1toF_5, respectively, whereas $F_1 \, to \, F_2$ represents the perceptions of M_1 to M_5 on the affected factors A, respectively. A_1 to A_n represents the sets of affected factors by misinformation factors, respectively. The overall similarity between misinformation factors is calculated using equation (1).

2.3.2. Find the Nearest Neighbors using the s_4 similarity formula

This analysis considered the (Augustine 2020) proposed similarity measures for finding the nearest neighbors between M_1 to M_5 to identify the most influencing misinformation factor. The $\boldsymbol{s}_4$ similarity measure is represented in equation (2).

$$s_4(A,B) = 1 - \frac{1}{4_n} \sum_{i=1}^{n} [|\mu_A(x_i) - \mu_B(x_i)| + ||\mu_A(x_i) - V_A(x_i)| - |\mu_B(x_i) - V_B(x_i)|| + ||\mu_A(x_i) - \pi_A(x_i)| - |\mu_B(x_i) - \pi_B(x_i)||] \quad (2)$$

Where, $\pi_A(x_1) = \sqrt{\mu_A^2 + V_B^2}$ and $\pi_B(x_1) = \sqrt{\mu_B^2 + V_B^2}$

Augustine (2020) proposed that s_4 is the optimized formula for handling real-time similarities, and so s_4 is used to measure the influencing factor. From the primary data, there is the respondent's count, which is used to analyze; let us represent it as (P). From the secondary data, a sample of five respondents' perceptions is collected and analyzed based on the misinformation factor, let that it be represented as (S_{M_i}). Let us consider a set of misinformation factors M = {M_1,M_2, M_3, M_4, M_5}, where M_1= Fake reporting M_2= Fake remedies, M_3= Conspiracy,M_4= Susceptibility, M_5= Vaccine rumors. Now, equation (2) is modified as equation (3).

$$s_4(P, S_{M_i}) = 1 - \frac{1}{4_n} \sum_{i=1}^{n} [|\mu_P(x_i) - \mu_{S_M}(x_i)| + ||\mu_P(x_i) - V_P(x_i)| - |\mu_{S_M i}(x) - V_{S_M}(x_i)|| + ||\mu_P(x_i) - \pi_P(x_i)| - |\mu_{S_M}(x_i) - \pi_{S_M}(x_i)||] \quad (3)$$

In equation (3), first, find the π value for both primary and secondary data. For example:

$M_1 =$ $\mu_P(M_1) = 0.82$, $\mu_{S_F}(M_1) = 0.28$, $V_P(M_1) = 0.18$, and $V_{S_F}(M_1) = 0.11$

$$\pi_A(M_1) = \sqrt{\mu_P^2 + V_P^2}$$

$$= \sqrt{1 - 0.82^2 + 0.18^2}$$

$$= \sqrt{1 - 0.6724 + 0.0324}$$

$$= \sqrt{1 - 0.7048}$$

$$= \sqrt{0.2952}$$

$$\pi_P(M_1) = 0.5433$$

$$\pi_{S_F}(M_1) = \sqrt{\mu_{S_F}^2 + V_{S_F}^2}$$

$$= \sqrt{1 - 0.28^2 + 0.11^2}$$

$$= \sqrt{1 - 0.0784 + 0.0121}$$

$$= \sqrt{1 - 0.0905}$$

$$= \sqrt{0.9095}$$

$$S_F(M_1) = 0.9975$$

After finding the π values for both primary and secondary data and applying those values in equation (3). For example:

$$M_1 = \mu_P(M_1) = 0.82,\ \mu_{S_F}(M_1) = 0.28,\ V_P(M_1) = 0.18, \text{ and } V_{S_F}(M_1) = 0.11,$$
$$\pi_P(x_1) = 0.5433,\ S_F(x_1) = 0.9975$$

$$= s_4(P, S_{M_i}) = 1 - \frac{1}{4*5}\sum_{i=1}^{5}[|0.82 - 0.28| + ||0.82 - 0.18| - |0.28 - 0.11|| + ||0.82 - 0.5433| - |0.28 - 0.9975||]$$

$$= 0.54 + |0.64 - 0.17| + |0.2767 - 0.7175|$$

$$=0.54 + 0.47 + 0.4408$$

$$M_1=1.4508$$

After calculating the remaining factors, such as M_2=0.4618, M_3=0.4096, M_4=1.2962, and M_5=0.5127.

2.3.3. Predict the highest perceptions of the misinformation factor

This section predicts which misinformation factor has the highest values that are more influencing and spreading the fake COVID-19 information among the people. For example, the M_i factor will be predicted using equation (3).

$$s_4(P, S_{M_1}) = 1 - \frac{1}{20}\sum_{i=1}^{5} 1.4508 + 0.4618 + 0.4618 + 1.2962 + 0.5127$$

$$1 - 0.05 * 4.1311$$

$$1 - 0.2065$$

$$s_4(P, S_{M_1}) = 0.7935$$

After predicting the remaining factors' values, such as $s_4(P, S_{M_2}) = 0.7499$, $s_4(P, S_{M_3}) = 0.7122$, $s_4(P, S_{M_4}) = 0.7676$, $s_4(P, S_{M_5}) = 0.7491$. From the proposed analysis, $s_4(P, S_{M_i}) = 0.7935$ has the highest value than other factors. So, the reporters have wrongly spread misinformation about COVID-19 among the people.

2.4. Affected Factor by Misinformation-Based CF Recommendation Algorithm

2.4.1. Calculate the Similarity between Misinformation factors using cosine similarity

Cosine similarity is being used to assess responders' perceptions depending on elements that may be represented as a vector of n-dimension, and the similarity of the components is determined by the angle of the respondents' perception vector. In general, the greater the similarity, the smaller the angle.

The perceptions of the respondents are typically characterized as the perception vector $P_A\{P_{A_1}, P_{A_2}, \ldots . P_{A_5}\}$. The similarity between the five misinformation factors is determined by comparing their perception vectors. Cosine similarity is the traditional metric for calculating factor similarity. In cosine similarity, first, the respondent's perception is gathered, which represents the n-dimensional vector, and then, the similarity among factors is calculated based on the angle of the factors perception vector. In general, the greater the similarity, the smaller the angle. This calculation used the secondary values for findings the similarity as well as considering the highest respondent's perception values for calculating the similarity. This calculation is similar to the Similarity between Misinformation factors using cosine similarity.

2.4.2. Find the Nearest Neighbors using the s_4 similarity formula

From the secondary data, a sample of five respondents' perceptions are collected and analyzed based on the affected factors by misinformation, let that it be represented as (S_{A_i}). Let us consider a set of misinformation factors A = $\{A_1, A_2, A_3, A_4, A_5\}$, where A_1= social media, A_2= Vitamin D prevents corona, A_3= Political Corona Conspiracy, A_4= Socio-Economic susceptibility, A_5= More side effects after getting vaccinated. Now, calculate the nearest neighbor to affected factors using eq (3).

In equation (3), first, find the π value for both primary and secondary data. For example:

$$A_1 = \mu_P(A_1) = 0.82,\ \mu_{S_F}(A_1) = 0.26,\ V_P(A_1) = 0.18, \text{ and } V_{S_F}(A_1) = 0.16$$

$$\pi_A(A_1) = \sqrt{\mu_P^2 + V_P^2}$$

$$= \sqrt{1 - 0.82^2 + 0.18^2}$$

$$= \sqrt{1 - 0.6724 + 0.0324}$$

$$= \sqrt{1 - 0.7048}$$

$$= \sqrt{0.2952}$$

$$\pi_P(A_1) = 0.5433$$

$$\pi_{S_F}(A_1) = \sqrt{\mu_{S_F}^2 + V_{S_F}^2}$$

$$= \sqrt{1 - 0.26^2 + 0.16^2}$$

$$= \sqrt{1 - 0.0676 + 0.0256}$$

$$= \sqrt{1 - 0.0932}$$

$$= \sqrt{0.9068}$$

$$S_F(A_1) = 0.9522$$

After finding the π values for both primary and secondary data and applying those values in eq (3). For example:

$$A_1 = \mu_P(A_1) = 0.82,\ \mu_{S_F}(A_1) = 0.26,\ V_P(A_1) = 0.18, \text{ and } V_{S_F}(A_1) = 0.16,$$
$$\pi_P(x_1) = 0.5433, S_F(x_1) = 0.9522$$

$$= s_4(P, S_{A_4}) = 1 - \frac{1}{4*5}\sum_{i=1}^{5}[|0.82 - 0.26| + ||0.26 - 0.18| - |0.26 - 0.16|| + ||0.82 - 0.5433| - |0.28 - 0.9522||]$$

$$= 0.56 + |0.08 - 0.1| + |0.2767 - 0.6922|$$

$$=0.56 + 0.02 + 0.4155$$

$$A_1=0.9955$$

After calculating the remaining factors, such as A_2=0.7887, A_3=1.2336, A_4=1.7345, A_5=1.589

2.4.3. Predict the highest perceptions of the misinformation factor

This section predicts which affected factor has the highest values that are more caused by COVID-19 misinformation among the people. For example, the A_i factor will be predicted using eq (3).

$$s_4(P, S_{A_1}) = 1 - \frac{1}{20}\sum_{i=1}^{5} 0.9955 + 0.7887 + 1.2336 + 1.7345 + 1.589$$

$$1 - 0.05 * 6.3413$$

$$1 - 0.31706$$

$$s_4(P, S_{A_1}) = 0.6829$$

After predicting the remaining factors' values, such as $s_4(P, S_{A_2}) = 0.6906$, $s_4(P, S_{A_3}) = 0.6991$, $s_4(P, S_{A_4}) = 0.6977$, $s_4(P, S_{A_5}) = 0.7488$. From the proposed analysis, $s_4(P, S_{A_5}) = 0.7488$ has the highest value than other factors. Hence, the factor of getting more side effects after being vaccinated is the highly affected misinformation among the people.

3. Results and discussion

3.1 Similarity measure

Table 1 contains the s1 to s6 formulas and similarity calculated values between (x, y), (x, z), and (y, z).

Table 1 Analysis of the similarity measure.

Formulas	Similarity Measure		
	S (x, y)	S (x, z)	S (y, z)
s_1	0.8690	0.7813	0.9224
s_2	0.9224	0.7837	0.9479
s_3	0.8711	0.7211	0.9244
s_4	0.6745	0.6978	0.7235
s_5	0.8739	0.7817	0.9327
s_6	0.8773	0.7765	0.9410

Figure 3 represents the similarity measure using different similarity formulas. When comparing that, s4 calculates the accurate similarity of others as it provides the greatest similarity calculation between x and y, y and z, and x and z, respectively. Though S_1, s2, s3, s5, and s6 only satisfy the respective condition, it also calculates the approximate similarity more than s4.

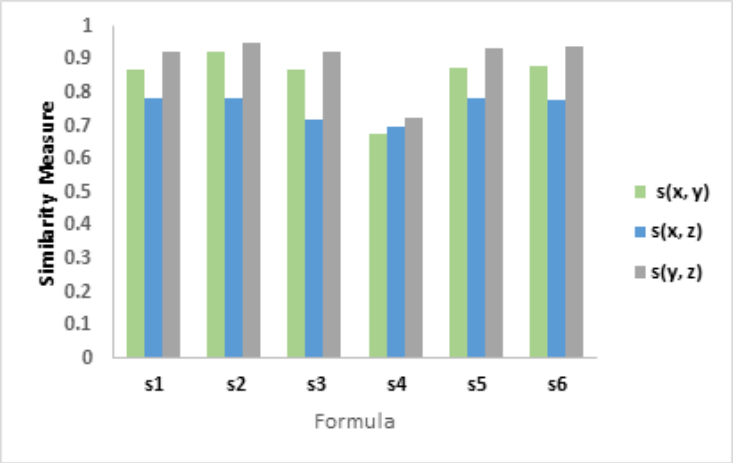

Figure 3 Compare the similarity.

3.2 Belief percentage measure

Table 2 contains the percentage values of both belief and non-belief respondents based on the vaccine rumors.

Table 2 Calculate the belief percentage among people.

Vaccine rumors	Percentage%	
	Belief	Non-belief
Scared of covid-19 vaccines	53	47
Chronic disease	68	32
Smoking	62	38
More side effects caused by a vaccine	93	7
Food/drug allergies	82	18

Figure 4 demonstrates that nearly 50 % of the respondents were initially concerned about the side effects of COVID-19 vaccination. Nearly 68% of the members' believed in chronic diseases based on the rumors before vaccination, as well as 62% of respondents believed that smokers are not to take the vaccine. 93% of respondents wrongly believed that there are more

side effects caused by a vaccine. 83% of respondents believed that due to food and drug allergies, people are not taking a vaccine.

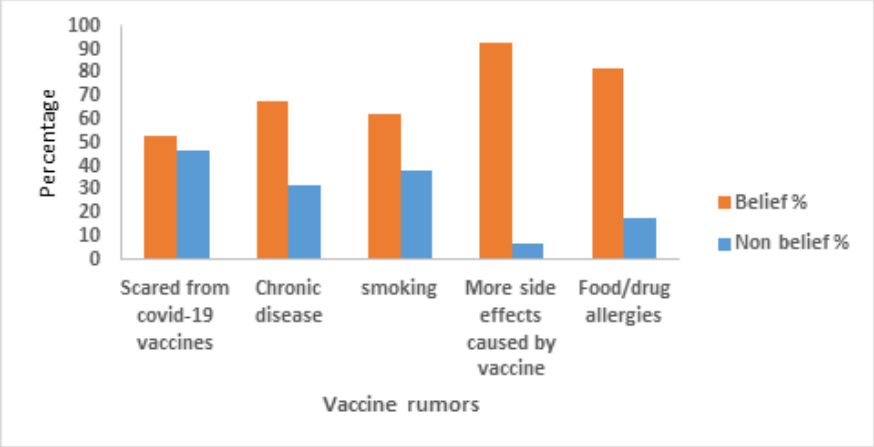

Figure 4 Compares the percentage of vaccine-based rumors between belief and non-belief.

3.3 Precision, Recall, and F-measure

Table 3 contains Precision, f-measure, and recall values for four different algorithms (Collaborative filtering, Model-based CF, Memory-based CF, and MBCFWS4).

Table 3 Precision, Recall, and F-measure comparison.

Parameters	CF (Alhijawi et al 2021)	Model-based CF (Zarzour et al 2020)	Memory-based CF (Ghazarian and Nematbakhsh 2015)	MBCFWS4
Precision	0.96	0.92	0.94	0.95
Recall	0.94	0.97	0.96	0.98
F-measure	0.93	0.94	0.98	0.99

The proposed approach performed better than the baseline works (CF, Model-based CF, and Memory-based CF), as seen in Figure 5. From the analysis, the precision, recall, and F-measure values are low for the existing works. Due to the issues of CF based techniques (Alhijawi et al 2021), it is unable to identify the latent relationship between the related factors. When there are no prior ratings from the people, CF has trouble making accurate suggestions. Then, the memory-based CF model (Ghazarian and Nematbakhsh 2015) suffers from data sparsity, which happens when the users score only a few factors out of a huge number of factors provided. Furthermore, when the number of users and factors rises, the processing complexity will also increase, resulting in limited scalability and difficulty in making suggestions. The model-based approaches need a significant amount of time and memory to create the model and may result in information loss when dimensionality reduction is used. Finally, the proposed approach's performance is found to be better in terms of Accuracy, F-score, and recall. As because the suggested approach lowers uncertainty and ambiguity, lowering these two factors will result in less confusion in decision-making and more efficiency in uncertain circumstances.

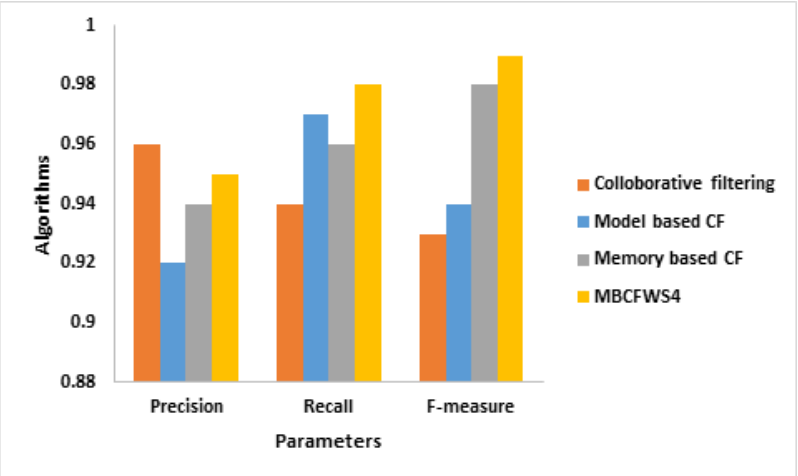

Figure 5 Compare the precision, recall, and F- measure.

3.4. Findings

One of the most important essential things for humans is the healthcare system. The COVID-19 pandemic is influenced by the availability of information, the majority of which is erroneous, causing a hazard to both physical and mental conditions. Despite the impact of sharing the COVID-19 pandemic misinformation, all people need to make the right decisions about COVID-19. This research found that the fake report factor has high impact and highly sharing of COVID-19 misinformation than all the others. Boards 2 and 3 depict the sample perceptions of the respondents on COVID-19 misinformation (M) and affected by misinformation (A) online. It is learned from the respondent's perception that most of the respondents' choice reporters are wrongly reporting on COVID-19. Public concern over COVID-19's incorrect or misleading content is placed on social media. Also, from the primary data analysis found in (Board 1), it is clear that counting based 82% of respondents gave their opinion that they are unsatisfied with social media.

4. Conclusions and recommendations

This study introduced a novel method for discovering fake health-related information, and it will aid in the detection of false information on COVID pandemic issues. The proposed work makes the factor-based analysis to conclude the more impact factor from the respondent's side. This analysis of the primary and secondary datasets helps to identify and collect the perceptions of the respondent's that are in the MBCFWS4 measure. In the MBCFWS4 process, first, the factors are categorized into two types, namely misinformation-based CF and affected by misinformation-based CF. The misinformation-based factor analysis found that the fake report factor has the most impact on the respondent's side and was affected by misinformation-based factor analysis found that social media has highly spread COVID-19 misinformation from the respondent's perception. Hence, it is recommended to avoid sharing COVID-19-based misinformation among the people. In state-of-the-art work, similarity measure of s4 is the optimized formula to measure the similarity between one or more variables and parameters. So, this analysis used s4 for calculating all the values based on factors during evaluation. From the efficiency analysis, the precision, f-score, and recall of the CF-based proposed work are higher than the baseline works. Also, 93% of respondents wrongly believed that more side effects were caused by the COVID vaccine, which is found from the belief percentage analysis. The study ends with a discussion of various limitations, which are associated with the data source, the schematization of misinformation, and the time required for data collection. More research is needed to better comprehend the contents, origins, effects, and further key components of COVID-19 misinformation in India, according to this analysis, which found a few knowledge gaps.

4.1. Recommendations

Some platform organizations capitalized on COVID-19 data centers and specialized knowledge panels, and they presented health authority information in several ways. They have also witnessed misinformation, prominent anti-vax organizations, and occasionally radical lockdown demonstrators, as well as concerted intimidation of journalists and specialists employed on COVID-19. The platforms most commonly utilized as a source of information or news on coronavirus vary by country, although in virtually all cases, Google Search, Facebook, Twitter, YouTube, and WhatsApp having high popularity. From the proposed analysis, it was found that the fake report factor has a high impact on COVID-19 misinformation because, from early 2020, social media had highly shared fake information about the COVID-19 pandemic.

List of Abbreviations

CF	Collaborative filtering
COVID	Coronavirus
MBCF	Memory-based collaborative filtering

Ethical considerations

Before taking part in the study, all individuals provided informed consent. The study was carried out under the Helsinki Declaration, and the protocol was approved by the Ethics Committee.

Conflict of Interest

The authors declare that they have no conflict of interest.

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References

Pak A, Adegboye OA, Adekunle AI, Rahman KM, McBryde ES, Eisen DP (2020) Economic consequences of the COVID-19 outbreak: The need for epidemic

preparedness. Frontiers in Public Health 8. DOI: 10.3389/fpubh.2020.00241

Roozenbeek J, Schneider CR, Dryhurst S, Kerr J, Freeman AL, Recchia G, Van der Bles AM, Van der Linden S (2020) Susceptibility to misinformation about COVID-19 around the world. Royal Society Open Science 7:201199. DOI: 10.1098/rsos.201199

Elhadad MK, Li KF, Gebali F (2020) Detecting misleading information on COVID-19. IEEE Access 8:165201. DOI: 10.1109/access.2020.3022867

Al-Zaman MS (2021) A thematic analysis of misinformation in India during the COVID-19 pandemic. International Information and Library Review 1. DOI: 10.1080/10572317.2021.1908063

Ejegwa PA (2020) New similarity measures for Pythagorean fuzzy sets with applications. International Journal of Fuzzy Computation and Modelling 3:75. DOI: 10.1504/ijfcm.2020.106105

Peng X (2018) New similarity measure and distance measure for Pythagorean fuzzy set. Complex and Intelligent Systems 5:101. DOI: 10.1007/s40747-018-0084-x

Chen R, Hua Q, Chang Y, Wang B, Zhang L, Kong X (2018) A survey of collaborative filtering-based recommender systems: From traditional methods to hybrid methods based on social networks. IEEE Access 6:64301. DOI: 10.1109/access.2018.2877208

Hatmal MM, Al-Hatamleh MA, Olaimat AN, Hatmal M, Alhaj-Qasem DM, Olaimat T, Mohamud R (2021) Side effects and perceptions following COVID-19 vaccination in Jordan: A randomized, cross-sectional study implementing machine learning for predicting severity of side effects. Vaccines 9:556. DOI: 10.3390/vaccines9060556

Roy S, Ghosh P (2020) Factors affecting COVID-19 infected and death rates inform lockdown-related policymaking. PLOS ONE 15:e0241165. DOI: 10.1371/journal.pone.0241165

Wang J, Wang Z (2020) Strengths, weaknesses, opportunities and threats (SWOT) analysis of China's prevention and control strategy for the COVID-19 epidemic. International Journal of Environmental Research and Public Health 17:2235. DOI: 10.3390/ijerph17072235

Tariq Soomro Z, Waseem Ilyas SH, Yaqub U (2020) Sentiment, count and cases: Analysis of Twitter discussions during COVID-19 pandemic. 2020 7th International Conference on Behavioural and Social Computing (BESC). DOI: 10.1109/besc51023.2020.9348291

Junlan Z, Chengke Y (2020) Data-analysis-based discussion on COVID-19 pandemic shocks to the economy and policy responses: Cases in the United Kingdom. 2020 Management Science Informatization and Economic Innovation Development Conference (MSIEID). DOI: 10.1109/msieid52046.2020.00109

Ma X, Wang J, Qin H, Wang Y (2020) Public opinion analysis about the coronavirus COVID-19 based on micro-blog data. 2020 International Conference on Information Science and Education (ICISE-IE). DOI: 10.1109/icise51755.2020.00104

Vrindavanam J, Srinath R, Shankar HH, Nagesh G (2021) Machine learning based COVID-19 cough classification models – A comparative analysis. 2021 5th International Conference on Computing Methodologies and Communication (ICCMC). DOI: 10.1109/iccmc51019.2021.9418358

Alhijawi B, Al-Naymat G, Obeid N, Awajan A (2021) Novel predictive model to improve the accuracy of collaborative filtering recommender systems. Information Systems 96:101670. DOI: 10.1016/j.is.2020.101670

Ghazarian S, Nematbakhsh MA (2015) Enhancing memory-based collaborative filtering for group recommender systems. Expert Systems with Applications 42:3801. DOI: 10.1016/j.eswa.2014.11.042

Bhalse N, Thakur R (2021) Algorithm for movie recommendation system using collaborative filtering. Materials Today: Proceedings. DOI: 10.1016/j.matpr.2021.01.235

Nielsen RK, Schulz A, Fletcher R (2021) An ongoing infodemic: How people in eight countries access news and information about Coronavirus a year into the pandemic. Availale in: https://reutersinstitute.politics.ox.ac.uk/ongoing-infodemic-how-people-eight-countries-access-news-and-information-about-coronavirus-year Accessed on: November 4, 2021.

Ilie PC, Stefanescu S, Smith L (2020) The role of vitamin D in the prevention of coronavirus disease 2019 infection and mortality. Aging: Clinical and Experimental Research 32:1195.

Pummerer L, Böhm R, Lilleholt L, Winter K, Zettler I, Sassenberg K (2021) Dataset for: Conspiracy theories and their societal effects during the COVID-19 pandemic [Data set]. PsychArchives. Availale in: https://www.psycharchives.org/handle/20.500.12034/4095 Accessed on: November 4, 2021.

Augustine EP (2020) New similarity measures for Pythagorean fuzzy sets with applications. International Journal of Fuzzy Computation and Modelling 3:75. DOI: 10.1504/ijfcm.2020.10027701

Zarzour H, Jararweh Y, Al-Sharif ZA (2020) An effective model-based trust collaborative filtering for explainable recommendations. 2020 11th International Conference on Information and Communication Systems (ICICS). DOI: 10.1109/icics49469.2020.239555

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Development and validation of an ultraviolet spectrophotometric method for Saquinavir estimation in bulk and dosage form

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Abstract We developed and validated a simple, rapid, sensitive, precise, and reproducible specific UV spectrophotometric technique for determining Saquinavir in bulk medication and pharmaceutical dosage form. Methods: As per ICH recommendations, a simple double-beam UV spectrophotometric technique has been designed and validated with several criteria, such as linearity, precision, repeatability, the limit of detection (LOD), limit of quantification (LOQ), and accuracy. Results: UV-visible spectrophotometric approach, measurement of absorption at the maximum wavelength in 10 mL methanol, and volume made with water solvent system as reference Saquinavir was discovered at 239 nm. The medicine followed Beer's rule and showed a good correlation. Beer's law was followed for Saquinavir in the 1-5µg/ml concentration range, with a correlation coefficient of 0.999. Saquinavir's LOD and LOQ were determined to be 0.56 µg/ml and 2.78 µg/ml, respectively. The proposed method is simple, precise, accurate, and reproducible, and it may be utilized for routine analysis of Saquinavir in bulk and tablet dosage form.

Keywords: rapid method, accurate, beer's law

1. Introduction

The anti-retroviral medicine saquinavir (SQR) is structurally related to the related pharmaceuticals famciclovir and tenofovir (2S) -N-[(2S,3R) -4-[(3S) -3-(tert-butyl-carbamoyl)-decahydroisoquinolin-2-yl] -3-hydroxy-1 phenylbutan-2-yl] — 2-(quinolin-2-ylformamido) butanediamide (Figure 1)—the protease inhibitor saquinavir. Proteases are enzymes that hydrolyze, or break apart, protein molecules. HIV replication within a cell and the release of mature viral particles from an infected cell both need the presence of HIV protease. HIV-1 and HIV-2 proteases are blocked by saquinavir (Figgitt 2000; Winston 2006).

Bioanalytical method validation in protein-free human plasma for the antiretroviral drugs amprenavir, nelfinavir, ritonavir, saquinavir, delavirdine, and efavirenz (Mu 2021) using extensive liquid chromatography; a novel RP-HPLC method for estimation of the protease inhibitor saquinavir (Mu 2021). Proust (2000) Nelfinavir, Indinavir, Ritonavir, Saquinavir, and Amprenavir in human plasma using a liquid chromatography-mass spectrometry technique (Proust 2000). RP-HPLC method for simultaneous quantifying indinavir, amprenavir, ritonavir, saquinavir, and nelfinavir in human plasma (Sarasa-Nacenta 2001).

Determination of Multiple HIV Drugs Using Reversed-Phase High-Performance Liquid Chromatography (HPLC)in Human Plasma (Droste 2003), Determination of Multiple HIV Drugs Using Reversed-Phase High-Performance Liquid Chromatography in Human Plasma (Notari 2006), and Determination of Multiple HIV Drugs Using Reversed-Phase High-Performance Liquid Chromatography in Human Plasma (Hoetelmans 1997) High-performance liquid chromatography for the simultaneous detection of anti-HIV medicines in human plasma (Notari 2006). It used ion-pair high-performance liquid chromatography with UV detection (Hoetelmans 1997) to quantify saquinavir in human plasma, saliva, and cerebrospinal fluid. Saquinavir, an HIV-1 protease inhibitor, was measured in the brain and testes of mice using high-performance liquid chromatography (Mudigonda 2006). Saquinavir concentration in Caco-2 cell monolayers using high-performance liquid chromatography-ultraviolet (HPLC-UV) (Ucpinar 2003). According to the literature, as mentioned earlier review, there is currently no method that has been described for the estimate of a drug that is simple, precise, reproducible, and accessible in terms of sample preparation. Therefore, a spectroscopic approach for the quantification of saquinavir in bulk and capsule dosage form using 20% methanol was devised in the present work. The established strategy is very targeted, accurate, and validated. In terms of cost, this

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strategy is efficient. The developed procedure was validated by ICH and USP standards (Savic 2008; USP 2003). On the validation data, the appropriate statistical tests were run (Bolton 1997).

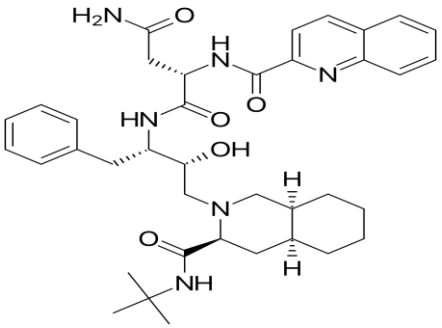

Figure 1 Structure of Saquinavir.

2. Materials and Methods

2.1. Materials and reagents

In the present investigation, Analytical method validation was performed using a Shimadzu UV/Visible twin beam spectrophotometer (Model 1700) and 1cm matched quartz cells. Saquinavir was provided as a gift sample by R. S. I. T. C. in Jalgaon. They used HPLC-grade methanol (Merck Specialities Pvt. Ltd., Shiv Sager Estate 'A' Worli, Mumbai) for the UV technique. The solvent employed in the investigation was a mixture of methanol and acidic water (0.05% OPA) made in double-distilled water. Saquinavir, 500 mg tablets, was purchased from a drugstore (Maximum 500- Cipla Pharmaceuticals Ltd).

2.2. Stock solution preparation

2.2.1. Stock Saquinavir solution

10 mg of Saquinavir (SQR) was dissolved in Methanol in a 10ml volumetric flask to make a 1000 µg/ml solution

2.2.2. Preparation of Stock Standard Solution

Carefully measure 10 mg of the Saquinavir working standard into a 10 ml volumetric flask and dilute it with Methanol until you get a concentration of 1000 µg/ml (stock solution). Once the standard has been sonicated for 15 minutes to dissolve, 0.1 ml of the stock solution should be transferred to the 10 ml volumetric flask - the result (Figure 2).

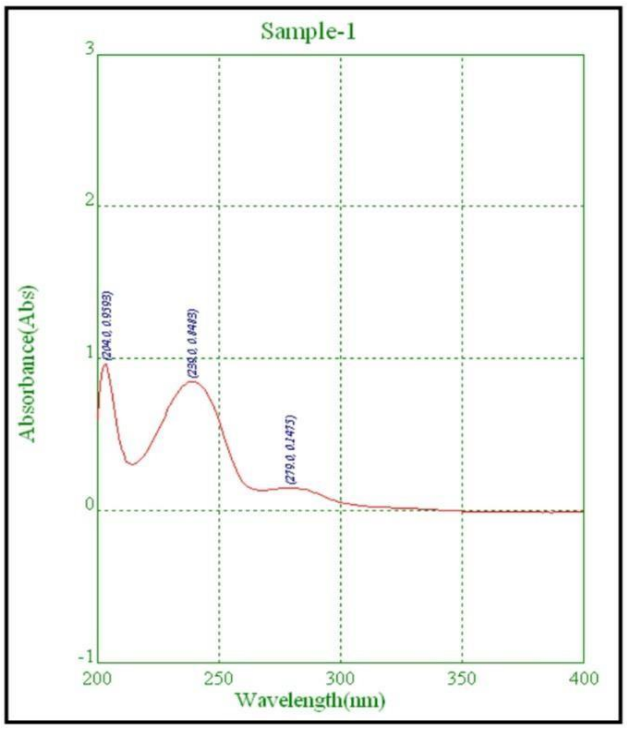

Figure 2 UV Spectrum of Saquinavir.

2.3. Procedure for calibration curve of Saquinavir

When the results from the calibration trials were analyzed using linear regression, a linear relationship was discovered between the peak regions and concentrations between 1 and 5 µg/mL of Saquinavir (Table 1). Saquinavir's concentration was best described by the linear equation y = 0.202x-0.195, where x represents the concentration and y represents the area of the peak obtained by UV spectrometry. The correlation coefficient was 0.999. Saquinavir's standard curve for dose-response is shown in (Figure 3).

2.4. Selection of detection wavelength

Saquinavir has its absorbance maximum (lambda max) at 239 nm when scanned against 10 ml of Methanol, and a volume made with a water solvent system is used as a standard.

Table 1 Linearity data for Saquinavir.

Conc µg/ml	Peak área (µV.sec) 1	2	Average peak area (µV.sec)	S.D. of Peak Area	% RSD of Peak Area
1	0.3938	0.3944	0.39	0.00	0.11
2	0.6026	0.6035	0.60	0.00	0.11
3	0.8059	0.8056	0.81	0.00	0.03
4	1.001	0.999	1.00	0.00	0.14
5	1.204	1.209	1.21	0.00	0.29
Equation			Y = 0.202x+0.0195		
R^2			0.999		

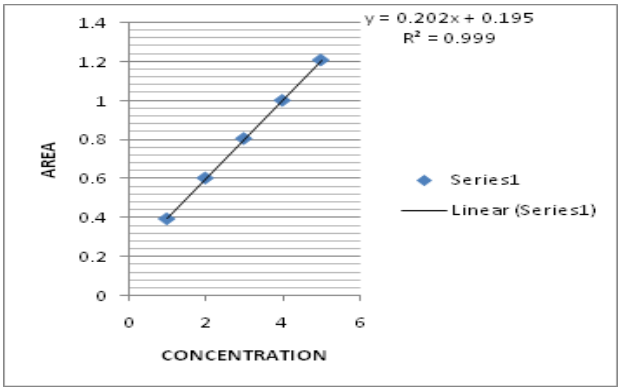

Figure 3 Calibration curve of Saquinavir.

2.5. Procedure for analysis of tablet formulation

Accurately weigh and transfer the sample amounting to 13.3mg Saquinavir into a 10 ml volumetric flask (20 tablets were used to get the average weight of 1330 mg). Sonicate it in roughly 10 ml of diluents to completely dissolve it, then add more diluents to bring the volume up to the required level. Incorporate thoroughly, then filter through a 0.45 µm membrane. As mentioned above, pipetanother 0.2 ml of the stock into a 10 ml volumetric flask, and dilute to the desired concentration (20 µg/ml) with the appropriate solvents. Saquinavir doses per tablet were determined by extrapolating the calibration curve's area value. Five separate iterations of the analysis technique were performed with the tablet iteration. Marketed formulation analysis included labeling as well. Evaluation: 99.99–101.00% successful results achieved (Table 2).

Table 2 Analysis of marketed formulation.

Drug	Label Claimed	Amt. Found	% Lable Claim	SD	% RSD
SQR	2	2.03	101.50	0.02	07
	2	2.04	101.50	0.01	07

2.6. Method validation

The linearity, precision, accuracy, limit of detection, and limit of quantification of the suggested methods have all been validated in compliance with ICHQ2 (R1) standards (Sudha 2012; Prasad 2012; Mante 2017; Ahmad 2022).

3. Results

3.1 Linearity and range

When the results from the calibration trials were analyzed using linear regression, a linear relationship was discovered between the peak regions and concentrations between 1 and 5 µg/mL of Saquinavir (Table 1). Saquinavir's concentration was best described by the linear equation y = 0.202x-0.195, where x represents the concentration and y represents the area of the peak obtained by UV spectrometry. The value of the correlation coefficient was a perfect 1.00. Saquinavir's standard curve for dose-response is shown in (Figure 3).

3.2 Accuracy

To ensure the efficacy of the new approach, recovery tests were conducted. Table 3 shows the results of adding standard medication at three different concentrations (80%, 100%, and 120%) to the already-analyzed tablet solution and calculating the recovery. Studying the recovery at 100%, 100%, and 120% concentrations confirmed the accuracy of the UV spectroscopic approach. The range of the percentage recovery was found to be 99-101%.

3.3 Statistical Analysis

Verification of the statistical recoveries is mentioned in Table 4. The results were analyzed using GraphPad Prism software, the quick calls option online. The Mean, Standard Deviation was calculated after taking at least three to six readings for UV Method. Relative Standard Deviation (RSD) and Correlation coefficient were also calculated.

Table 3 Result of recovery data for Saquinavir.

Drug	Level (%)	Amt. taken (µg/ml	Amt. Added (µg/ml	Absorbance Mean* ± S.D.	Amt. recovered Mean *±S.D.	%Recovery Mean *± S.D.
	80%	2	1.6	3.62 ± 0.01	2.02 ± 0.07	101.03 ± 0.80
SQR	100%	2	2	1.012 ± 0.01	2.03 ± 0.01	101.5 ± 0.35
	120%	2	2.4	1.09 ± 0.01	2.43 ± 0.16	102.08 ± 0.29

*mean of each three reading for the UV method.

Table 4 Statistical validation of recovery studies Saquinavir.

Drug	Level (%)	Mean % Recovery	Standard Deviation*	% RSD
	80%	101.89	0.98	0.96
SQR	100%	97.53	1.27	1.30
	120%	101.58	0.21	0.20

*Denotes an average of three determinations for the UV method.

3.4 Precision

Saquinavir test method precision was investigated to characterize intra- and inter-day shifts. Analysis of three concentrations in three replication measurements within the linearity range of medications at three different times on the same day was used to calculate intraday precision (Table 6). The system was run generally for three days while interday precision was measured. The high precision% amount from 98% to 100% suggests the analytical method that concluded Table 5 from the research of intraday and interday precision on UV method for Saquinavir.

Table 5 Result of Intra day and Inter day Precision studies for Saquinavir.

Drug	Conc (µg/ml)	Intraday Precision		Interday Precision	
		Mean± SD	%Amt Found	Mean± SD	%Amt Found
	2	1.974 ± 0.01	99.77	2.015 ± 0.01	102.70
SQR	3	2.994 ±0.02	100.08	2.973 ±0.02	99.20
	4	3.926 ±0.01	99.89	4.0132 ±0.01	101.25

*Mean of each 3 reading for UV method.

3.5 System suitability parameters

Table 6 Repeatability studies on the UV method for Saquinavir.

Conc	Absorbance	Amt Found	% Amt Found
3	0.8055	3.02	100.67
3	0.8053	3.02	100.67
3	0.8056	3.02	100.73
3	0.8059	3.02	100.80
3	0.8053	3.02	100.67
	Mean	3.02	100.71
	SD	0.00	0.06
	%RSD	0.06	0.06

3.6 Limit of detection (LOD) and Limit of quantification (LOQ)

Under the specified experimental conditions, LOD is the minimal analyte concentration in a sample that can be detected. The limit of quantification (LOQ) refers to the lowest concentration of an analyte in a sample that can be determined with acceptable precision and accuracy using the methods and equipment available. Both 0.56 and 2.78 micrograms per milliliter were determined to be the LOD and LOQ, respectively, for saquinavir.

4. Discussion

The proposed approaches for the simultaneous estimate of saquinavir in tablet dosage forms were straightforward, precise, cost-effective, and quick (Shukla et al 2022). ICH Q2 (R1) standards confirmed the method to be reliable. At these particular wavelengths, the correlation coefficient (r2) for saquinavir obtained from standard calibration was 0.999. Recovery rates for both medicines came close to 100%, and the values of % RSD were well within the allowed range of 2%. Examining pharmaceutical formulations shows that the suggested method can simultaneously determine these components with minimal interference from other additives (Chavan et al 2022).

To summarize, saquinavir in formulations can be successfully estimated simultaneously using the abovementioned techniques (Ahmad 2022). UV-Vis spectroscopy can only be used to measure solutions, which is its primary limitation. It cannot be used to measure samples of solids or gases. Also, it is affordable and easily accessible. Further Studies can be done towards the development or refinement of saquinavir-based therapies. These specific methods and results presented can assist scientists across the globe in developing saquinavir-based therapies and their quality control (Gaikwad et al 2011).

5. Conclusion

Results showed that the new UV spectrophotometric approach was more exact, accurate, and repeatable than previous methods regarding linearity, precision, range, and robustness. In addition, it was observed that the procedures were straightforward and efficient. Therefore, all the methodologies presented are practical for use in quality assurance labs as part of their everyday procedures.

Abbreviations

UV stands for ultraviolet. HPLC stands for High-Performance Liquid Chromatography. HPTLC is for High-Performance Thin Layer Chromatography, and ICH stands for International Conference on Harmonization. UPLC stands for Ultra-Performance Liquid Chromatography. SQR stands for Saquinavir; RSD stands for Relative Standard Deviation; RT stands for Retention Time; and SD stands for Standard Deviation.

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

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References

Figgitt DP, Plosker GL (2000) Saquinavir soft-gel capsule. Drugs 60(2):481–516.

Winston A, Back D, Fletcher C, Robinson L, Unsworth J, Tolowinska I, Boffito M (2006) Effect of omeprazole on the pharmacokinetics of saquinavir-500 mg formulation with ritonavir in healthy male and female volunteers. Aids 20(10):1401–1406.

Mu Y (2021) Combating HIV-1 by Targeting Drug Efflux Transporters on the Macrophage Reservoir (Doctoral dissertation, The University of Tennessee Health Science Center).

Proust V, Toth K, Hulin A, Taburet AM, Gimenez F, Singlas E (2000) Simultaneous high-performance liquid chromatographic determination of the antiretroviral agents amprenavir, nelfinavir, ritonavir, saquinavir, delavirdine and efavirenz in human plasma. Journal of Chromatography B: Biomedical Sciences and Applications 742(2):453-458.

Chi J, Jayewardene AL, Stone JA, Motoya T, Aweeka FT (2002) Simultaneous determination of five HIV protease inhibitors nelfinavir, indinavir, ritonavir, saquinavir, and amprenavir in human plasma by LC/MS/MS. Journal of Pharmaceutical and Biomedical Analysis 30(3):675–684.

Sarasa-Nacenta M, López-Púa Y, Mallolas J, Blanco JL, Gatell JM, Carné X (2001) Simultaneous determination of the HIV-protease inhibitors indinavir, amprenavir, ritonavir, saquinavir, and nelfinavir in human plasma by reversed-phase high-performance liquid chromatography. Journal of Chromatography B: Biomedical Sciences and Applications 757(2):325-332.

Droste JAH, Verweij-van Wissen CPWGM, Burger DM (2003) Simultaneous determination of the HIV drugs indinavir, amprenavir, saquinavir, ritonavir, lopinavir, nelfinavir, the nelfinavirhydroxymetabolite M8, and nevirapine in human plasma by reversed-phase high-performance liquid chromatography. Therapeutic

drug monitoring 25(3):393-399.

Notari S, Bocedi A, Ippolito G, Narciso P, Pucillo LP, Tossini G, Ascenzi P (2006) Simultaneous determination of 16 anti-HIV drugs in human plasma by high-performance liquid chromatography. Journal of Chromatography B 831(1-2):258-266.

Hoetelmans RM, van Essenberg M, Meenhorst PL, Mulder JW, Beijnen JH (1997) Determination of saquinavir in human plasma, saliva, and cerebrospinal fluid by ion-pair high-performance liquid chromatography with ultraviolet detection. Journal of Chromatography B: Biomedical Sciences and Applications, 698(1-2):235-241.

Mudigonda K, Jukanti R, Apte SS, Ajjala DR, Shrivastava W, Kandikere VN, Nirogi RV (2006) HPLC quantification of the HIV-1 protease inhibitor saquinavir in brain and testis of mice. Biomedical Chromatography 20(10):1028-1032.

Ucpinar SD, Stavchansky S (2003) Quantitative determination of saquinavir from Caco-2 cell monolayers by HPLC-UV. Biomedical Chromatography 17(1):21-25.

Gaikwad AV, Rajurkar VG, Shivakumar T, Dama GY, Tare HL (2011) Simultaneous estimation of ramipril & valsartan in tablets by HPTLC. Indo-Global Journal of Pharmaceutical Sciences 1(1):99-112.

Savić I, Nikolić G, Banković V (2008) Development and validation of spectrophotometric method for phenylephrine hydrochloride estimation in nasal drops formulations. Macedonian Journal of Chemistry and Chemical Engineering 27(2):149-156.

United states pharmacopoeia (2003) in the validation of compendia methods, 26th ed, Pharmacopeial Convention, Inc., Rockville, MD, 2439-2442.

S. Bolton (1997) in Pharmaceutical Statistics: Practical and clinical application, 3rd ed, Marcel Dekker, New York, 216–264.

Mante GV, Gupta KR, Hemke AT (2017) Estimation of dapagliflozin from its tablet formulation by UV-spectrophotometry. Pharmaceutical Methods 8(2):102–107.

Ahmad S, Khairnar M, Bakhshi AR, Tare M, Baheti D, Tare H (2022) QBD approach to developing stability indicating RP-HPLC method development for levosulpiride and ilaprazole. International Journal of Health Sciences 6(S5):7413–7429.

Sudha T, Krishana KV, Nukala PCS, Saloman RT, Ganesan V (2012) Method development and validation. Journal of Advanced Pharmacy Education and Research 2(3):146-176.

Prasad PVD (2012) Isocratic reverse phase high-performance liquid chromatographic estimation of ramipril and amlodipine in pharmaceutical dosage form. Journal of Advanced Pharmacy Education and Research 2(3):137-145.

Shukla S, Sharma N, Singh S, Arora S, Rani A (2022) Preformulation and uv-spectrophotometric analytical method validation studies for assessment of canagliflozin. International Journal of Pharmaceutical Quality Assurance 13(3):290-295.

Chavan PB, Kolhe MH, Dhamak KV (2022) Stability indicating method development and validation of carvedilol and ivabradine in bulk and its formulation by rp-hplc method. International Journal of Drug Delivery Technology 12(3):1350-1356.

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Forecasting municipal solid waste generation using linear regression analysis: A case of Kathmandu Metropolitan City, Nepal

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Abstract There is lack of study predicting the Municipal Solid Waste (MSW) output scientifically and accurately for least developed countries like Nepal. Previous studies have primarily relied on the tentative amount of waste generation linked with the number of vehicles involved in waste collection and transfer to the landfill site. This study used linear regression analysis to forecast the solid waste generation of Kathmandu Metropolitan City (KMC) by undertaking past population data and solid waste generation. The SPSS analysis resulted in a strong relationship between population and solid waste generation with a coefficient of 0.956. A linear regression validation was performed to ensure that the derived formula is statistically significant. The finding indicates the r squared (R^2) value to be 0.913, leading the waste prediction model to be very strong. The prediction equation of 0.659X - 204222.952 resulted in an average waste generation of KMC as 1006 t/d on average till 2035 with an average per capita/d waste generation of 0.54 kg. The current MSW generation of KMC is found to be 766 t/d and predicted to reach 1259 t by 2035. The information can be helpful for the municipality and urban planning authorities to make strategies for effective management of waste generated in KMC, creating less burden at the Banchare Danda landfill site.

Keywords: Dumpsite, Landfill, Kathmandu, prediction, waste management

1. Introduction

Solid waste management is a major issue faced by urban areas of the globe. Though the cities have made advancements in introducing proper systems and technologies, the amount of solid waste has been increasing trend. There is a lack of integrated solid waste management systems and green technology (Saxena and Srivastava 2022), which has caused severe risks to human health and the environment (Gumel 2022). The consumption pattern of a commodity varies from one individual to another. It is necessary that an individual identifies their role towards sustainable consumption patterns (Khanal 2021b) so that it wouldn't cause any negative impact on the environment. In order to achieve sustainable municipal solid waste management, it is necessary to understand the mechanism related to solid waste generation.

The world generates around 2.01 Bt of municipal solid waste annually with 0.74 kg/capita/d, and this is expected to reach 3.40 Bt by 2050 (Kaza et al 2018). The amount of municipal solid waste (MSW) generation is in increasing trend every year due to rapid urbanization and population growth (Sharma, Ganguly, and Gupta 2018; Khanal 2021b). Not only population, there is also a correlation between income and waste generation (Reno 2015). The amount of waste generation will increase as the year passes by. The average waste generation in Asia was 0.52 kg/capita/d, which was lower than the global of 0.74 kg/capita/d in 2016 (Kaza et al 2018) but predicted to increase by an average of 40% in the countries like Bangladesh, Sri lanka, Pakistan, Afghanistan, Bhutan, and India by 2050.

The total municipal solid waste generation of Nepal is about 1,435 t/d with 317 gram/capita/d (ADB 2013). Kathmandu Valley generates the highest amount of solid waste in Nepal (Khanal Giri and Mainali 2023), with the maximum waste transferred to the Sisdol landfill site (Khanal Sondhi and Giri 2021). Kathmandu is facing urban environmental crises with labor-intensive waste handling practices and a poor disposal system (Pandey 2004; Khanal and Giri 2016). There is a lack of a proper solid waste management system in Kathmandu, with ineffective waste collection, transfer, treatment, and disposal resulting in a spike in solid waste generation in recent decades (Khanal 2021a; Khanal 2023).

This study has used the past data of MSW generated in Kathmandu Metropolitan City (KMC) and made a prediction for the future's solid waste generation. Municipal solid waste includes both household and commercial waste (World Bank 2018). Household waste is also called domestic or residential waste, which is generated from houses, including kitchen waste, paper, bottles, cans, cloths, green waste and others. While commercial waste is generated from corporate houses, institutions and

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organizations, mostly including dry materials. Assigned waste collectors collect the generated waste. There is no fixed route of transportation of collected solid waste to the transfer station and landfill site as it solely depends on drivers (Alam et al 2008). Though the waste collection timetable has been shared with households and institutions, the service is irregular. In KMC, private companies are very active (Khanal 2021a) and play an important role by collecting waste from 25 different wards (Figure 1). Both public and private companies have important roles in solid waste management (Guerrero et al 2013). There were 18 private organisations in 2014 involved in the waste management of KMC (Singh et al 2014) which has currently increased to 31 by 2021. KMC has now identified two companies, Nepwaste and Clean Valley Pvt. Ltd., for managing the overall solid waste of Kathmandu Valley (World Bank 2016). The appointed companies have submitted plans for integrated solid waste management (ISWM) of Kathmandu Valley with the usage of modern technologies. The environment friendly waste recovery machinery will increase work efficiency with less burden on human resources. On the other hand, it is equally challenging to integrate the current waste management service provider.

In the past, the organic waste was managed at the household level in Kathmandu using home compost bins called "*saagas*", and the remaining waste was reused and recycled (Singh et al 2014). There are a handful of private companies and organisation practising green technologies for organic waste, including vermicomposting and windrow composting, yet it is rarely used on mega-scale for commercial purposes. The first landfill was constructed in 1984 at Gokarna with the help of German Technical Cooperation (GTZ) and another landfill site at Sisdole with the help of the Japan International Cooperation Agency (JICA) in 2005 (Dangi et al 2009). The municipal solid waste of KMC is currently disposed of at the Sisdol landfill site located in the Nuwakot district (Khanal et al 2021). Table 1 shows the history of solid waste management in Kathmandu, Nepal (JICA 2005; Pokhrel and Viraraghavan 2005; Bahadur et al 2015). The researchers agree that the government has failed in the sound management of the landfill, leading to a negative impact on the surrounding environment.

Table 1 History of solid waste management in Kathmandu, Nepal.

Date	Details
1919	*Safai Adda* was established and sanitation duties were provided to the workers, which was later renamed as Municipality Office.
1980	Nepal received its first solid waste management aid from GTZ.
1984	A landfill was constructed at Gokarna to manage the waste of Kathmandu Valley.
1988	The solid waste act was introduced to control the haphazard dumping of solid waste, which covered three cities of Kathmandu Valley.
1994	The Gokarna landfill site was closed and waste was dumped nearby the Bishnumari River.
2005	A new landfill was operated at Sisdol.
2011	Introduced solid waste management act, which focuses on waste minimization.
2019	The Five Year Plan 2019/2020 has set a goal for processing the waste generated in Kathmandu Valley by establishing a modern sanitary landfill site at Banchare Danda by 2023.
2022	The construction of 'Cell One' of the Banchare Danda landfill site was completed and waste was dumped at the Banchare Danda Landfill site for the first time on May 24, 2022.

The Solid Waste Management Act 2011 of Nepal focuses on decentralized solid waste management practices and has asked Local Authority (LA) to adopt the Integrated Solid Waste Management (ISWM) system (Maharjan et al 2019). The modern waste management strategy needs to give priority to handling the waste at source (Giri 2021). Household source segregation helps in increasing the value of waste (Khanal 2022). The waste collector also needs to collect the solid waste in a segregated form, which eases the recyclable extraction process. Sustainable Development Goal 11 has a target to reduce the adverse per capita impact of cities by 2030. Also, Goal 12 focuses on the reduction, recycling and reuse of waste. The solid waste generation data helps with the effective management of solid waste generated in a city.

The solid waste generation data from the government and other institutions vary widely in Kathmandu. There is no uniformity in the data gathered from the study conducted by the government, institutions, organizations or even individual researchers. A survey conducted in 2007 found the municipal solid waste generation of KMC as 523.8 metric t/d or 0.66 kg/capita/d, and it was higher than 320 metric t reported by the government (Dangi et al 2011). Another study shows solid waste generation in KMC in 2005 as 245 t and in 2006 as 260 t/d (Alam et al 2008). The report prepared by KMC on solid waste generation is incomplete as it only calculates the waste collected for disposal purposes (Dangi et al 2011). There is a lack of solid waste generation data with KMC as it only presents the tentative data based on waste collection and disposal at the Sisdol landfill site. In most of these cases, KMC generates data based on the number of trips carried by the tripper (trucks) from the Teku transfer station to the Sisdol landfill site. The regression analysis has been used globally to predict solid waste generation. Researchers in Kuwait (Al-Salem et al 2018), Thailand (Sun and Chungpaibulpatana 2017), Romania (Ghinea et al 2016), Mexico (Benítez, Lozano-Olvera, Morelos, and Vega 2008; Buenrostro, Bocco, and Vence 2011), Iran (Azadi and Karimi-Jashni 2016) and India (Kumar and Samadder 2017) have developed a model using regression. This study is the first of its kind to be used in Nepal for predicting the municipal solid waste of Kathmandu. The solid waste prediction equation can be used to find the waste

generation of KMC on a yearly basis. The waste composition and quantity of solid waste differs in an urban and rural setting. This study is limited to predicting urban solid waste generation

2. Materials and Methods

The KMC generated the highest amount of MSW in Nepal and was purposively chosen for this study. Kathmandu is the capital city of Nepal and is located in the South Asian region. It lies at an average altitude of 1350 m above sea level (Thapa et al 2008). There are 32 wards in KMC where the MSW is collected by both government and private companies (Figure 1).

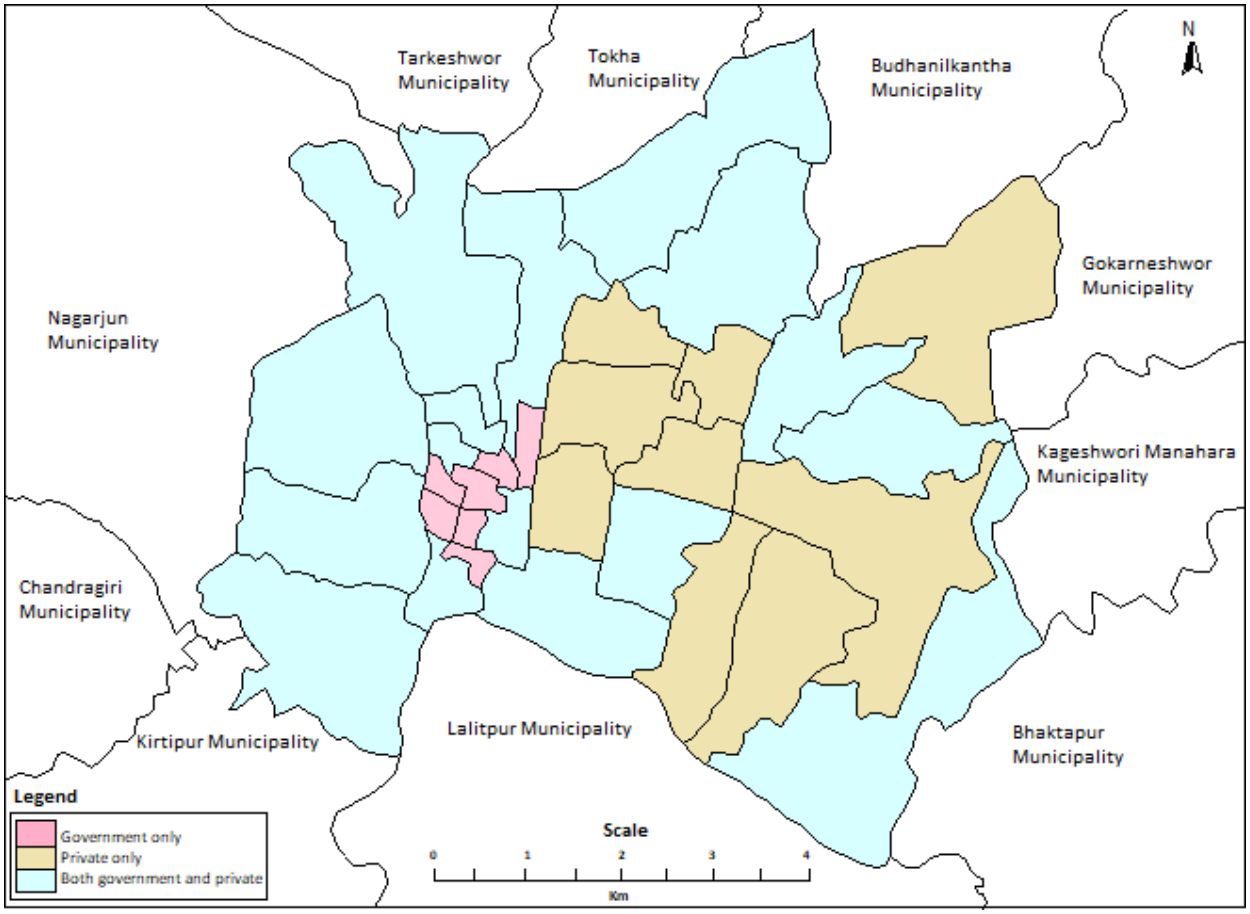

Figure 1 Map of KMC showing waste collection areas of public and private parties.

Statistical Package for the Social Sciences (SPSS) was used for the development of the MSW generation model for KMC. The population and MSW generation from 2005-2013 were considered for this study. After 2013, no record of MSW generation for KMC was found for every consecutive year after that. So the MSW generation and population data was used from 2005-2013.

The Linear Regression Equation is given as:

$$Y = a + bX \qquad (1)$$

Where Y is the dependent variable (amount of MSW);
X is the independent variable (population of KMC);
b is the slope;
a is the y-intercept.

The secondary data for population and MSW was used for this study (Table 2). The MSW generation data of KMC from 2005 to 2013 has been considered as the dependent variable and the population has been taken as the independent variable for this study. The past data of population and MSW generation of KMC was used to determine the regression coefficient. The annual waste generation of KMC from 2005-2013 was extracted from the Environment Statistics of Nepal report published by the Central Bureau of Statistics (CBS 2019). The population (from 2005-2013 and 2021-2035) of KMC used in this study was extracted from the United Nations population prediction data (United Nations 2022).

Table 2 Population and municipal solid waste generation of Kathmandu from 2005-2013.

Year	Population	MSW generation (t)
2013	1088000	524
2012	1045000	492
2011	1004000	480
2010	965000	435
2009	927000	365
2008	890000	354
2007	855000	343
2006	822000	338
2005	790000	336

3. Results and discussion

The obtained data of the population of KMC from 2005-2013 and the respective MSW generation data were entered in the SPSS to perform the regression.

The prediction equation was found as:

$$0.659X - 204222.952 \quad (2)$$

Where X is the population for a particular year.

The R-value was found to be 0.956, which shows a high degree of correlation between population and waste generation. In 2007, a study conducted in Kathmandu also found the coefficient of correlation to be 0.94 (Dangi et al 2011). Though there are other socioeconomic variables (population density, income, GDP) for forecasting the MSW generation, the population trend is widely used by researchers (Khan and Burney 1989; Wei et al 2013; Ghinea et al 2016; Azadi and Karimi-Jashni 2016; Araiza-Aguilar et al 2020). The coefficient of 0.956 obtained for solid waste generation of KMC is also near to the study conducted in Mexico, which found a coefficient of 0.975 (Araiza-Aguilar et al 2020). The MSW generation for KMC was calculated using the above prediction equation till 2035 (Table 3). The analysis showed that the average MSW generation of KMC is 1006 t/d till 2035, with an average per capita/d waste generation of 0.54 kg. The obtained value is within the range of 0.5-0.75 kg per capita/d for low-income countries (Cointreau 2006). The linear regression validation was also performed to know how the obtained data fits within the line. The r-squared (R^2) value was calculated for the regression model validation (Ghinea et al 2016) and was found to be 0.913 showing the obtained model to be very strong.

Table 3 Municipal solid waste generation forecast for Kathmandu with household waste and per capita.

Year	Municipal solid waste generation per d (t)	MSW generation per capita/d (kg)	Household waste generation per d (t)	HHs waste generation per capita/d (kg)
2021	766	0.52	528	0.36
2022	798	0.52	550	0.36
2023	831	0.53	572	0.36
2024	865	0.53	595	0.37
2025	898	0.54	617	0.37
2026	933	0.54	640	0.37
2027	967	0.54	663	0.37
2028	1002	0.55	687	0.38
2029	1038	0.55	711	0.38
2030	1074	0.55	735	0.38
2031	1110	0.56	760	0.38
2032	1147	0.56	785	0.38
2033	1184	0.56	810	0.38
2034	1221	0.56	835	0.39
2035	1259	0.57	860	0.39

The MSW for KMC for 2021 was found to be 766 t/d and is forecast to reach 1259 t by 2035, as shown in Figure 2. The MSW generation of KMC is predicted to increase by 64% in the next 15 years. As the current resources aren't adequate, it would be much more difficult for KMC to manage the MSW in the coming years. There is an urgent need for waste management technologies for efficient collection, treatment, and disposal.

The study found that household waste occupies 69% of the MSW. This finding was within the range as specified by a study conducted in Nepal in 2012 which claimed the HHs waste to be 50%–75% of the total MSW (ADB 2013). The major portion of household waste is occupied by organic matter. If organic waste can be managed at the household level, it would drastically decrease waste generation. The high volume of waste generation, lack of collection space, and the presence of dump sites

cause serious health risks (De and Debnath 2016; Rana et al 2017; Chikaire et al 2022). The household needs to make aware of the impact of mixed waste and help them realize their role in environmental protection. The direct handling of mixed waste can also cause infectious and chronic diseases to the waste workers. Exposure to different hazardous wastes affects human health and also impacts the environment.

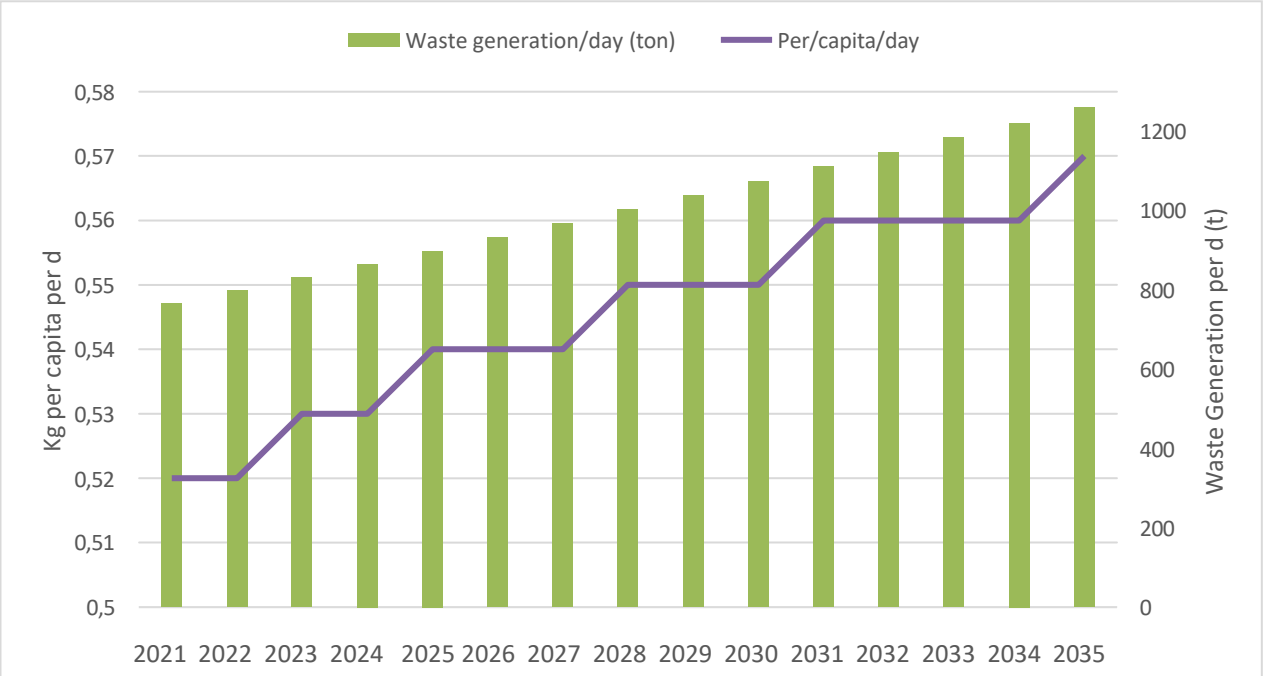

Figure 2 Municipal solid waste generation forecast for Kathmandu Metropolitan City.

4. Conclusions

The conclusions from the study were derived as follows:

- A strong relationship was found between the population and solid waste generation of Kathmandu, with a coefficient of 0.956.
- The prediction equation for MSW generation of Kathmandu was found to be 0.659X - 204222.952.
- The R^2 value was found to be 0.913 showing the obtained waste prediction model to be very strong.
- The MSW generation of Kathmandu was found to be 1006 t/d on average till 2035 with an average per capita/d waste generation of 0.54 kg.
- The MSW generation of Kathmandu was 766 t in 2021 and is forecast to reach 1259 t/d by 2035. The study found that household solid waste occupies 69% of the total MSW generated in KMC.
- The prediction equation for MSW generation will be helpful for the municipality to forecast the waste generation and deploy human resources and allocate the budget accordingly.

The government should promote educational campaigns for waste reduction, which will benefit humans and the environment. If the source segregation is properly implemented, the recyclables can be extracted properly, leading to less burden on the Banchare Danda landfill site.

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Ethical considerations

Not applicable.

Conflict of Interest

The author declares that there is no conflict of interest.

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References

ADB (2013) Solid Waste Management in Nepal: Current Status and Policy Recommendations. In Asian Development Bank (ADB). https://www.adb.org/sites/default/files/publication/30366/solid-waste-management-nepal.pdf

Al-Salem SM, Al-Nasser A, Al-Dhafeeri AT (2018) Multi-variable regression analysis for the solid waste generation in the State of Kuwait. Process Safety and Environmental Protection 119:172-180. DOI: 10.1016/J.PSEP.2018.07.017

Alam R, Chowdhury MAI, Hasan GMJ, Karanjit B, Shrestha LR (2008) Generation, storage, collection and transportation of municipal solid waste – A case study in the city of Kathmandu, capital of Nepal. Waste Management 28(6):1088–1097. DOI: 10.1016/J.WASMAN.2006.12.024

Araiza-Aguilar JA, Rojas-Valencia MN Aguilar-Vera RA (2020) Forecast generation model of municipal solid waste using multiple linear regression. Global Journal of Environmental Science and Management 6(1):1-14. DOI: 10.22034/GJESM.2020.01.01

Azadi S, Karimi-Jashni A (2016) Verifying the performance of artificial neural network and multiple linear regression in predicting the mean seasonal municipal solid waste generation rate: A case study of Fars province, Iran. Waste Management 48:14-23. DOI: 10.1016/J.WASMAN.2015.09.034

Bahadur M, Dangi E, Schoenberger, Boland J (2015) Foreign aid in waste management: A case of Kathmandu, Nepal. Habitat International 49:1-10. DOI: 10.1016/j.habitatint.2015.06.010

Benítez SO, Lozano-Olvera G, Morelos RA, Vega CA (2008) Mathematical modeling to predict residential solid waste generation. Waste Management. DOI: 10.1016/J.WASMAN.2008.03.020

Buenrostro O, Bocco G, Vence J (2011) Forecasting Generation of Urban Solid Waste in Developing Countries—A Case Study in Mexico. DOI: 10.1080/10473289.2001.10464258 51(1):86–93. DOI: 10.1080/10473289.2001.10464258

CBS (2019) Environemnt Statistics of Nepal 2019. https://cbs.gov.np/environment-statistics-of-nepal-2019

Chikaire JU, Ajaero JO, Atoma CN (2022) Socio-economic Effects of Covid-19 Pandemic on Rural Farm Families' Well-Being and Food Systems in Imo State, Nigeria. Journal of Sustainability and Environmental Management 1(1):18–21.

Cointreau S (2006) Occupational and Environmental Health Issues of Solid Waste Management Special Emphasis on Middle-and Lower-Income Countries. https://www.ircwash.org/sites/default/files/Cointreau-2006-Occupational.pdf

Dangi MB, Cohen RRH, Urynowicz MA, Poudyal KN (2009) Report: Searching for a way to sustainability: Technical and policy analyses of solid waste issues in Kathmandu. Waste Management and Research 27(3):295–301. DOI: 10.1177/0734242X08094951

Dangi MB, Pretz CR, Urynowicz MA, Gerow KG, Reddy JM (2011) Municipal solid waste generation in Kathmandu, Nepal. Journal of Environmental Management 92(1):240–249. DOI: 10.1016/J.JENVMAN.2010.09.005

De S, Debnath B (2016) Prevalence of Health Hazards Associated with Solid Waste Disposal- A Case Study of Kolkata, India. Procedia Environmental Sciences 35:201–208. DOI: 10.1016/J.PROENV.2016.07.081

Ghinea C, Drăgoi EN, Comăniţă ED, Gavrilescu M, Câmpean T, Curteanu S, Gavrilescu M (2016) Forecasting municipal solid waste generation using prognostic tools and regression analysis. Journal of Environmental Management 182:80–93. DOI: 10.1016/J.JENVMAN.2016.07.026

Giri S (2021) Integrated solid waste management: A case study of a hotel in Kathmandu, Nepal. International Journal of Multidisciplinary Research (IJMR) 7(5):264–268. DOI: 10.36713/epra7024

Guerrero LA, Maas G, Hogland W (2013) Solid waste management challenges for cities in developing countries. Waste Management. DOI: 10.1016/j.wasman.2012.09.008

Gumel DY (2022) Assessing Climate Change Vulnerability: A Conceptual and Theoretical Review. Journal of Sustainability and Environmental Management 1(1):22–31.

JICA (2005) The study on the solid waste management for the Kathmandu Valley. https://openjicareport.jica.go.jp/pdf/11808631_01.pdf

Kaza S, Yao LC, Bhada-Tata P, Van Woerden F (2018) What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. In World Bank. DOI: 10.1596/978-1-4648-1329-0

Khan MZA, Burney FA (1989) Forecasting solid waste composition — An important consideration in resource recovery and recycling. Resources, Conservation and Recycling 3(1):1–17. DOI: 10.1016/0921-3449(89)90010-4

Khanal A (2021a) Livelihood Status of Itinerant Waste Buyers in Kathmandu. Applied Ecology and Environmental Sciences 9(5):537–540. DOI: 10.12691/aees-9-5-4

Khanal A (2021b) Sustainable Living in Schools: A Study of Vajra Academy, Lalitpur. Current World Environment 16(2):472–476. DOI: 10.12944/CWE.16.2.13

Khanal A, Giri S, Mainali P (2023) The Practices of At-Source Segregation of Household Solid Waste by the Youths in Nepal. Journal of Environmental and Public Health 2023:6. DOI: 10.1155/2023/5044295

Khanal A (2022) Survey on usage of single use plastic bags in Nepal. IOP Conference Series: Earth and Environmental Science 1057:12008. DOI: 10.1088/1755-1315/1057/1/012008

Khanal A (2023) COVID-19 related symptoms and vaccination usage among informal waste workers of Kathmandu, Nepal. International Journal of Occupational Safety and Health 13:155–162. DOI: 10.3126/ijosh.v13i2.43929

Khanal A, Giri S (2016) Possibility of Community Based Solid Waste Management Project in Chuchepati, Kathmandu. Journal of Basic and Applied Engineering Research 3(1):6–8. DOI: 10.6084/m9.figshare.15164808

Khanal A, Sondhi A, Giri S (2021) Use of personal protective equipment among waste workers of Sisdol landfill site of Nepal. International Journal of Occupational Safety and Health 11(3):158–164. DOI: 10.3126/ijosh.v11i3.39768

Kumar A, Samadder SR (2017) An empirical model for prediction of household solid waste generation rate – A case study of Dhanbad, India. Waste Management 68:3–15. DOI: 10.1016/J.WASMAN.2017.07.034

Maharjan NB, Khanal A, Basnet S (2019) A Community-Based Approach on Solid Waste Management for Historical Townships of Kathmandu Valley, Nepal. 2nd Global Summit on Recycling and Waste Management. https://www.scitechnol.com/conference-abstracts-files/a-communitybased-approach-on-solid-waste-management.pdf

Pandey R (2004) Solid Waste Management Practice and Health Implication: A Case of Kathmandu Metropolitan City, Nepal. Himalayan Review.

Pokhrel D, Viraraghavan T (2005) Municipal solid waste management in Nepal: practices and challenges. Waste Management 25(5):555–562. DOI: 10.1016/J.WASMAN.2005.01.020

Rana R, Ganguly R, Gupta AK (2017) Evaluation of solid waste management in satellite towns of Mohali and Panchkula-India. Journal of Solid Waste Technology and Management 43(4):280–294. DOI: 10.5276/JSWTM.2017.280

Reno J (2015) Waste and Waste Management. Annual Review of Anthropology. DOI: 10.1146/annurev-anthro-102214-014146

Saxena A, Srivastava A (2022) Industry Application of Green Manufacturing: A Critical Review. Journal of Sustainability and Environmental Management 1(1):32–45.

Sharma A, Ganguly R, Gupta AK (2018) Matrix method for evaluation of existing solid waste management system in Himachal Pradesh, India. Journal of Material Cycles and Waste Management 20(3):1813–1831. DOI: 10.1007/S10163-018-0703-Z

Singh RK, Yabar H, Mizunoya T, Higano Y, Rakwal R, Singh RK (2014) Potential Benefits of Introducing Integrated Solid Waste Management Approach in Developing Countries: A Case Study in Kathmandu City. Journal of Sustainable Development 7(6). DOI: 10.5539/jsd.v7n6p70

Sun N, Chungpaibulpatana S (2017) Development of an Appropriate Model for Forecasting Municipal Solid Waste Generation in Bangkok. Energy Procedia 138:907–912. DOI: 10.1016/J.EGYPRO.2017.10.134

Thapa RB, Murayama Y, Ale S (2008). Kathmandu. Cities 25(1):45–57. DOI: 10.1016/J.CITIES.2007.10.001

United Nations (2022) Kathmandu, Nepal Metro Area Population 1950-2022. https://www.macrotrends.net/cities/21928/kathmandu/population

Wei Y, Xue Y, Yin J, Ni W (2013) Prediction of municipal solid waste generation in china by multiple linear regression method. International Journal of Computers and Applications 35(3):136–140. DOI: 10.2316/JOURNAL.202.2013.3.202-3898

World Bank (2016) Nepal - Health Sector Management Reform Program. https://documents1.worldbank.org/curated/en/484251472737164501/pdf/108120-REVISED-EA-P160207-Box396338B-PUBLIC-Disclosed-12-15-2016.pdf

World Bank (2018) Municipal solid waste management: A roadmap for reform for policy makers. https://openknowledge.worldbank.org/bitstream/handle/10986/30434/130055-WP-P162603-WasteManagement-PUBLIC.pdf

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Social security agency of health (BPJS health) implementation on dentures patient in USA community health center (Puskesmas USA) bone regency 2022

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Abstract Implementation of Social Security Agency of Health (SCAH) /BPJS for Dentures Patients at the Usa Community Health Center in Bone Regency 2022. Tooth loss is a problem that can interfere with dental and oral health. This study aims to explore the implementation of social security agency policies for dentures patients at the Usa Community Health Center in 2022. This type of research is a qualitative study using a *snowball sampling technique.* The results of this study found that the informants had understood the services for installing dental prostheses that were borne by BPJS Health. As for the information, they do not understand the tariffs for dental prostheses or dentures, which are included in the service being covered by BPJS Health. BPJS Health provides a number of medical services for the community, one of which is dental and oral care, in this case dental prostheses or dentures. From the input and process results it was found that for the implementation of BPJS Health for dental prostheses there are still indicators that are not fully achieved, such as the rates of prostheses or dentures which are still misinterpreted by some patients.

Keywords: community health center, social security agency, dentures patients

1. Introduction

Tooth loss is a problem that can interfere with dental and oral health. Tooth loss can be caused by several factors, such as periodontal disease, dental caries, trauma, impaction, orthodontics, hypoplasia, and severe attrition. Caries and periodontal disease are the most common factors causing tooth loss (Sari et al 2015).

Based on the National Health Research report, tooth loss at the age of 34-55 years is 0.4%, which increases at the age of 65 and over by 17.6%. The loss of one or more teeth can cause functional and aesthetic disorders that can affect the quality of life because, apart from affecting the physical condition, it can also affect mastication and speech functions. Tooth loss can also affect psychological conditions, causing a lack of self-confidence and limitations in social activities (Utama et al 2018). Losing teeth for a long time will cause pathological migration of the remaining teeth, decreased alveolar bone in *edentulous areas*, decreased masticatory function to speech disorders, and can affect the temporomandibular joint. An ideal occlusion should allow the mandible to straighten without occlusal obstacles when functional movements occur, especially in the posterior region, so that the load distribution be spread evenly (Ratnasari et al 2019).

Replacement of missing teeth can be done by making removable dentures or fixed dentures. Dentures are used to obtain good esthetics and functional conditions for the user. According to *the Glossary of Prosthodontic* removable dentures are divided into two, removable partial dentures and complete dentures(I and Herwanda, n.d.). Removable partial dentures are indicated to replace several teeth in edentulous areas and have good esthetics; while complete dentures are indicated for edentulous patients, the remaining teeth cannot be maintained and can no longer support the removable partial dentures. The components of a removable denture consist of tooth and base elements. The base is made of metal or acrylic (Sofya et al 2016).

BPJS Health makes it easier for the public to get dental health services, including dental examinations at first-level health facilities and at the hospitals that work with BPJS Health (Efendi et al 2022). Dental cares covered by BPJS Health include service administration, provision and delivery of referral letters, examinations, treatment, and medical consultations (Muchlis et al 2022). There are also additional services with limitations, such as dentures. Dentures are very important in maintaining the health of the periodontal tissues health the remaining teeth' stability. The need for dentures increases in the elderly due to physiological changes in their oral cavity, including tooth loss. The USA Community Health Center is a health center located in the Bone Regency area. The USA Community Health Center is one of the health service facilities with basic service standards

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which is currently still in Middle status. The mission of Usa Community Health Center is to increase quality, professional, equitable and affordable health services to the community efficiently and effectively, to increase the optimal degree of public health, to increase the independence of the community to behave in a healthy life and to increase cross-program and cross-sector cooperation. The USA Community Health Center is remote, and road access to the health center is still badly damaged. Based on an initial survey conducted by researchers, the number of outpatient visits in 2020 was:5,643 patients, and in 2021 there were 5,622 patients (Public Health Center 2021).

Based on this background, researchers are interested in researching the Implementation of BPJS for Dental Prostheses Patients at the USA Health Center, Bone Regency, in 2022. This research is important to see the extent of the role of health insurance in patients, especially dental care, in patients who use BPJS; why BPJS? Because this health insurance is mostly for the general public.

2. Materials and Methods

This research used a quantitative study method and snowball sampling technique. According to Sugiono, qualitative research is data collection techniques are carried out by triangulation (combined), data analysis is inductive /qualitative, and the results of qualitative research emphasize the meaning of generalization (Sugiono 2017).

A qualitative approach is an important approach to understanding a social phenomenon and the individual perspective studied. A qualitative approach is also one in which the research procedure produces descriptive data in the form of written or spoken words from the behavior of the people being observed (Wahyuni 2013).

The respondent characteristics are demonstrated in Table 1.

Table 1 Socio-Demographics Respondent.

No	Initial	Age	Sex	Jobs	Education
1	A	50 Years	Female	Head	Postgraduate
2	H	31 Years	Female	Dental Nurse	Bachelor
3	H	32 Years	Female	Dental Nurse	Bachelor
4	R	43 Years	Male	Patients	Senior high school
5	B	41 Years	Male	Patients	Senior high school
6	M	33 Years	Female	Patients	Junior high school
7	D	27 Years	Male	Patients	Senior high school
8	D	58 Years	Female	Patients	Bachelor

3. Results

This research was conducted at the USA Community Health Center from December 14 to December 31 2022. The type of research used in this study was qualitative research using a descriptive approach. Information was obtained through in-depth interviews. Data sources are people who are willing to provide the information called informants.

3.1 Characteristics of Informants

The informants involved in this study were the head of the community health center, dental nurses, and BPJS patients. Informants in this study as many as 8 people.

Annotation:
IK: Key informant
IP: Supporting Informants
IB: Ordinary Informant

3.2 Inputs

3.2.1 Dental prosthesis installation service

BPJS Health participants can be provided at health facilities (faskes), first-level, and advanced-level health facilities. Based on the results of interviews with ordinary informants regarding dental prosthesis installation services, the following answers were obtained:

"Yes, definitely, because as far as I know, health services are fully covered by BPJS".
(RH informant)
"For the installation of dentures, I can do it at the advanced level".
(Informant B)
"Yesterday, my upper dentures were installed, serviced and covered by BPJS".
(RH informant)

This is the same as the statement of the supporting informant, who said that dental prosthesis services could be provided by active BPJS Health participants. The following are the results of the interview:

"For the installation of dentures, you will be covered if your BPJS Health is active, if the first health facility cannot provide or requires further treatment, you can refer them to the advanced level of health facilities".
(Informant MK)
"For BPJS membership as long as it's active, it's the responsibility of BPJS health according to the first or advanced level of health facilities".
(KM informant)

The results of interviews with ordinary informants and supporting informants are the same as the statements of key informants, which state that:

"If you want to use BPJS Health for filling dentures, you can come directly to the First Level Health Facility according to the procedure and the rules".
(Informant MK)

3.2.2 Dental prostheses or dentures

Health BPJS participants with tooth loss according to medical indications and on the recommendation of a dentist. Based on the results of interviews with ordinary informants regarding dental prostheses or dentures, the following answers were obtained:

"Yeah, BPJS should cover it. Because it is in accordance with the instructions and directions of the dentist".
(RH informant)
"When I installed my dentures yesterday, there was an indication that dentures should be done by a dentist".
(DB informant)

This is the same as the statement of the supporting informant who said that tooth loss according to medical indications and on the recommendation of a dentist will be covered by BPJS. Following results of the interview:

"Not all dentures are covered by BPJS Health, there are indications".
(Informant MK)

The results of interviews with key informants and supporting informants are the same as the statements of ordinary informants, which state that:

"Yes, the installation of dentures / dental prostheses is an additional service according to medical indications and on the recommendation of a dentist. Usually this service is used for elderly people who have lost their teeth".
(Informant MK)

3.2.3 Replacement rates for dental prostheses or dentures

The maximum tariff for each jaw is IDR 500,000, Details per jaw for the installation of 1 to 8 teeth Rp.250,000, 9 to 16 teeth of IDR 500,000:

"My husband already uses BPJS, when he installs dentures he pays for each jaw".
(RH informant)
"The tariff for replacing dentures is according to BPJS".
(DT informant)
"I Replaced 2 dentures yesterday and was given a replacement tariff".
(MM informant)

This is the same as the statement of the supporting informant said that in the replacement rates of dental prostheses or dentures. Following results of the interview:

"The cost of installing dentures is covered by BPJS, but according to the limit which is determined. So it's all free, right?".
(Informant MK)

The results of interviews with key informants and supporting informants are the same as the statements of ordinary informants, although there are slight differences from ordinary informants, who state that:

"For the installation of 1-8 dentures, BPJS Health provides a subsidy of IDR 250,000 per jaw. So for 1 jaw around 9-16 teeth, participants will receive a subsidy of IDR 500,000. Meanwhile, for installation of dentures for 2 jaws at once, a subsidy of IDR 1 million will be given".
(Informant MK)

3.3 Process

3.3.1 Denture fitting service

BPJS Health participants can be provided at health facilities (faskes), first level and advanced level health facilities. How does the health center create an open environment and no blame so it's safe to do reporting if an incident happened. Based on the results of interviews with informants regarding denture installation services, researchers obtained answer as follows:

> *"To get the benefit from dental care services from* BPJS *Health, if participants choose the Puskesmas as the first health facility, then participants will get dental treatment from dentists who are a network of the health center concerned. In the first health facility, participants must complete the administrative process by showing the active BPJS Health's card. Participants must bring a BPJS card as well as a referral letter from the first health facility".*
> *(Informant MK)*

This is the same as the statement of the supporting informant who said that in the service of installing dentures, BPJS health could be provided. The following are the results of the interview:

> *"Dental and oral health services can be enjoyed by BPJS Health participants with the applicable conditions".*
> *(MB informant)*

3.3.2 Dental prostheses or dentures

Dental prostheses or dentures are functional assistive devices that replace lost teeth as a result of extraction or trauma. The goal is to restore the function of teeth, esthetics and oral cavity and restore self-confidence. Based on the results of interviews with informants about dental prostheses or dentures get answers as follows:

> *"Many of my upper teeth are missing, so the doctor suggested installing dentures".*
> *(Informant MK)*

As for other statements from informants who said they did not really know regarding the indications for a dental prosthesis. The following are the results of the interview:

> *"To maintain our gums".*
> *(LK informant)*

3.3.3 Replacement rates for dental prostheses or dentures

Denture Prices vary, but there are several rates for replacing dentures if you use BPJS. This is because the nominal amount is determined by the type of dentures and the price. The Following answers were obtained based on the result of interviews with informans regarding dental prostheses or dentures:

> *"You can, it costs IDR 250,000 per jaw".*
> *(MS informant)*
> *"Replacement of 1 maxillary tooth and 1 mandibular tooth. The cost to replace it is Rp. 500,000. But if you lose only 2 maxillary teeth, you will replace Rp. 250,000".*
> *(LS informant)*

3.4 Outputs

From the results of the interviews that the researchers conducted, there were still a number of patients who did not understand the replacement rates for dental prostheses due to a lack of information and explanations from the puskesmas regarding the reimbursement of dental prostheses rates.

4. Discussion

4.1 Inputs

4.1.1 Dental prostheses installation service

The results of the research conducted by the researchers was found that the informants had understood the services for installing dental prostheses that were borne by BPJS Kesehatan. Dental care services, namely installing dentures with free BPJS, can be carried out for everyone registered as a BPJS Health participant according to applicable procedures and conditions. Please note that the manufacture of dentures or dental prostheses is not fully covered by BPJS Kesehatan. This dental prosthesis is an additional service provided by BPJS Health with limitations. Because the funds to be used are in the form of subsidies from BPJS Health. Services for installing dentures with BPJS Health can be carried out at first-level or advanced Health Facilities, depending on the availability of tools and dentists. Dentures or dental prostheses will be given according to tooth loss according to medical indications and on the recommendation of a dentist.

This research is not in line with the research conducted by Darmawan, which states that the visits of patients seeking treatment at dental services at the puskesmas are more patients who have not been registered as JKN participants and JKN participants registered at other facilities (Darmawan and Thabrany 2017).

This is in line with research conducted by Juatodomi, namely, the manufacture of dentures requires quite a large amount of money. This is because patients do not use BPJS, and the manufacture and maintenance of dentures are quite expensive (Juatodomi 2016).

Individuals who participate in BPJS Health will have many benefits in matters of health financing and can be used as an effort to take advantage of the dental and oral health services provided.

4.1.2 Dental prostheses or dentures

The results of the research conducted by the researchers was found that the informants had understood dental prostheses or dentures. As long as the participant follows the procedures and conditions that apply, and the act of installing the dentures is based on clear medical indications determined by the dentist as a form of handling the participant's condition (not at the request of the participant himself) Then the costs can be covered by BPJS Health. This is because there are restrictions on usage, bearing in mind the funds used are in the form of subsidies.

This is not in line with research conducted by Jatuadomi, which described that all patients care and have the same goal to improve their appearance. Someone who has lost a tooth can also cause emotional disturbances such as feeling sad, and loss of self-confidence because it affects the appearance and causes difficulties in the pronunciation process if the tooth loss is in the front (anterior), causing speech disorders. Desire is influenced by the ability to need to use dentures to replace missing teeth so that tooth loss disorders can be overcome (Juatodomi 2016).

This research is in line with research conducted by Mangundap G, which states that the use of dentures according to indications is effective for masticatory function in the people of Pinasungkulan Village, Modoinding District (Mangundap et al 2019).

4.1.3 Replacement rates for dental prostheses or dentures

The results of the research conducted by the researchers found that there were still informants who did not understand the tariffs for replacing dental prostheses or dentures, including dental and oral care, which is included in the medical services covered by BPJS Health. Even so, before visiting a health facility, it is necessary to know what services the BPJS can cover. This is because not all dental procedures are covered by the government through the National Health Insurance (JKN) program. So that sometimes patients complain about the terms of claiming rates for replacement dental prostheses or dentures.

This is in line with research conducted by Jatuadomi, which states that patients use BPJS, which reduces the cost of manufacturing and care. If the patient does not use BPJS, then the manufacture of dentures will have an effect and be heavy on income (Juatodomi 2016).

This research is not in line with the research conducted by Fathul Rahman. The results of the questionnaire obtained the reasons for the research subjects not having denture treatment, among others because of, the expensive manufacture of dentures, fear of going to the dentist, anxiety about using dentures due to the experience of friends who swallowed dentures, and incomplete equipment and lack of dentist skills in making dentures (Fathul et al 2016).

Another study conducted by Mokodompit R from the results of his research found that dentures made by dentists are more expensive than dental artisans (Mokodompit 2015).

4.2 Process

BPJS Health provides a number of medical services for the community. One of them is dental and oral care, in this case, dental prostheses or dentures. This means that the price of dentures at the puskesmas is Rp. 0, or free if you use BPJS Health. Although the mention is only a snippet. Although maybe you will get a difference in price at each health center in each area.

4.3 Outputs

The input and process results found that for the implementation of BPJS for dental prostheses, there are still indicators that have not reached 100%, such as the replacement rates for dental prostheses or dentures, which are still misinterpreted by some patients who claim that the full cost of dental prostheses is paid for by BPJS.

This research is in line with research conducted by Suprianto A, which states that the outcome of the National Health Insurance (JKN) success rate is quite good. The percentage of health covered by BPJS Health in Bantul Regency reaches 73% of the population (Suprianto and Mutiarin 2017).

BPJS implementation standards for dental prostheses at the Puskesmas USA, it has been going very well, according to BPJS Health Rules.

5. Conclusions and suggestions

The implementation of BPJS No 1 of 2014 Article 52 Paragraph 1 is that dental and oral care that is covered has not been fully achieved properly due to several inhibiting factors in its implementation, such as human resources who do not understand the process of claiming dental prostheses rates. Policy standards have been carried out in accordance with BPJS Policy No. 1 of 2014 Article 52 Paragraph 1. The process of implementing BPJS No 1 of 2014 Article 52 Paragraph 1 is to help and relieve the community in terms of health financing. With the existence of the BPJS government program, in terms of community financing, it has been helped by this financing. The Usa Community Health Center (Puskesmas USA) at Bone Regency has implemented BPJS No. 1 of 2014 Article 52 Paragraph 1 even though there are indicators that have not been achieved. For this reason, it is necessary to carry out a re-evaluation of what needs to be corrected or rearranged, and socialization regarding the replacement rates for the patient itself must be carried out. It is hoped that the head of the puskesmas will carry out activities that will later be socialized to patients regarding dental and oral care that is covered by BPJS. It is better to make a guide that contains the flow of dental and oral services and effective ways of communicating with patients and families so that patients and their families get complete information.

Ethical considerations

This research has received ethical approval from the Universitas Muslim Indonesia Indonesian Number:10/2022. All participants signed the informed consent before the interview. Respondents who were not willing were excluded and considered as inclusion criteria.

Conflict of Interest

The authors declare that they have no conflict of interest.

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References

Darmawan IR, Thabrany H (2017) Reflections on the Implementation of National Health Insurance in Dentistry Services at Tangerang City First Level Health Facilities in 2017. DOI: 10.22146/jkki.v6i4.26438

Efendi S, Agus AI, Syatriani S, Amir H, Alam RI, Nurdin S, Batara AS, Ikhtiar M (2022) The Effect of Benson Relaxation on Quality of Sleep of Cancer Patients. DOI: 10.3889/oamjms.2022.8295

Fathul R, Debby S, Rasihan A (2016) Factors Affecting Demand for Dentures in the Elderly (Review of Treatment Costs, Anxiety and Facilities) Stomatognathic 8:43-47.

Juatodomi J (2016) Reasons for using removable dentures in dental polyclinic patients at BLU Prof. Dr. R.D. Kandou Manado. Journal of E-GiGi (EG) 4:24–29.

lRahmayani L, Herwanda IM (2013) The behavior of maintaining dentures on the maintenance of removable denture hygiene. PDGI Journal 62:83-9.

Mangundap, Wowor V, Mintjelungan C (2019) The Effectiveness of the Use of Removable Partial Dentures on the Chewing Function of the Community of Pinasungkulan Village, Modoinding District. Journal of E-Dental (EG) 7:13–18.

Mokodompit M (2015) Patient Perceptions of Acrylic-Based Denture Users Using Dentist Services in Mobagu City. Journal of E-GiGi (EG) 5:12–17.

Muchlis N, Amir H, Cahyani DD, Alam RI, Landu N, Mikawati M, Febrianti N, Junaidin J, Sinaga MRE (2022) The cooperative behavior and intention to stay of nursing personnel in healthcare management. DOI: 10.25122/jml-2022-0277

Public Health Center (2021) USA health center report. Available in: https://statehealthcompare.shadac.org/?gclid=CjwKCAiArY2fBhB9EiwAWqHK6mmVztYZGGwbjirnTLb9SL1g8AhZBwdRTX3y8Z2zJn3XV9k2vQwX6RoC1EAQAvD_BwE. Accesssed on: August 27, 2022.

Ratnasari D, Isnaeni RS, Fadilah RPN (2019) Hygiene of Removable Dentures in the Age Group of 45-65 years. DOI: 10.24198/pjdrs.v3i2.23573

Sari SD, Ariana YMD, Ermawati T (2015) Relationship between Oral Dental Health Knowledge and Oral Hygiene Status in the Elderly. Journal of IKESMA 11:45-9.

Sofya PA, Rahmayani L, Fatmawati F (2016) Cleanliness of acrylic resin removable partial dentures in terms of frequency and cleaning method. J Shia Kuala Dent Soc 1:91–94.

Sugiono (2017) Educational Research Methods Quantitative, Qualitative, and R&D Approaches (1st edition) Alphabeta, Bandung.

Suprianto A, Mutiarin D (2017) Evaluation of the Implementation of the National Health Insurance. Journal of Government and Public Policy 8:67–69.

Utama IGKP, Putu SL, Ketut S (2018) Description and Factors Associated with the use of dentures in the elderly population in Selemadeg Village Tabanan Regency 2:72-6.

Wahyuni W (2013) Development of Case Study Journal Collection at UIN Sunan Kalijaga Library (1st edition) UIN Sunan kalijaga, Yogyakarta.

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Influential study of oxygenated additives in waste cooking biodiesel blends on diesel engine performance

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Abstract The rapid increase in energy demand brought on by the global population boom has led to a surge in the popularity of recycling waste materials into usable energy sources. That is to say, turning trash into usable energy will soon be a hot topic. More and more people are becoming aware of the benefits of biodiesel as a way to lessen their environmental impact by replacing their regular diesel fuel with a cleaner alternative. Usually, biodiesel is produced by mixing vegetable oils with animal-based oils. Because of its low production cost and low environmental impact, waste cooking oil (WCO) is suitable for biodiesel research. Using oxygenated fuels appears to be a practical strategy for lowering engine pollution. The purpose of this study is to examine the effects of varying ratio of diethyl ether (DEE) additives and waste cooking oil biodiesel on the efficiency and emissions of a diesel engine. Emission parameters were evaluated in comparison to those of pure diesel, and results were optimized for various load conditions and mixtures of oxygenated additives. The engine efficiency of WCO and DEE blends of 20% was found to be around 5.2% greater than that of standard diesel, while fuel consumption was reduced by 15%. Additionally, additives lowered CO emissions by 7-9% and HC emissions by 9%. The data were subsequently evaluated using the design of experiment tool, "Full Factorial Design" to establish the most optimal running condition with fuel consumption of 0.2720 kg/kWh, hydrocarbon of 50 ppm and carbon monoxide 0.277% at maximum load circumstances by the 20% fuel mixes.

Keywords: waste to energy, waste cooking oil, biodiesel, diesel engine, emission, optimization

1. Introduction

The lack of renewable energy and the consequences of global warming are the two biggest problems facing humanity in the twenty-first century. Increases in both population and per capita income have resulted in a dramatic increase in the global demand for energy. Effective utilization of energy resources is fundamental to human progress because of its profound impact on improving people's standard of living. Access to sufficient energy sources is crucial to economic development in any country. All sectors of society, including farming, manufacturing, shipping, shopping, and households, require some type of energy (Panwar et al 2011). The rising usage of fossil fuels to meet the high energy needs of industrialized countries and the residential sector has resulted in new environmental contamination issues. The generation of electricity from fossil fuels has a number of concerns for human health and the environment and may have long-term implications for global climate change (Degfie et al 2019). Since there has been a rise in environmental concerns, scientists are actively investigating renewable energy options. Some examples of renewable energy are wind, hydropower, solar electricity, biomass, and biofuels. Biodiesel is one potential solution to the problem of how to meet economic and environmental demands (Li et al 2014).

Alternatives to fossil fuels and the damage they cause to the environment are being researched, and biodiesel and diesel fuel blends are one of the possibilities being looked into. Transesterification of plant or animal lipids yields biodiesel, which can be used as a diesel fuel substitute. Waste cooking oil is seen as a competitive alternative to vegetable oil in the biodiesel industry due to its lower production costs (Venkatesh et al 2021). As an added bonus, turning WCO into a fuel source helps prevent the pollution that would result from dumping it. Because it uses recycled cooking oil and generates less pollution than alternative methods, WCO's biodiesel manufacturing is good for the environment. It's useful since it lessens the demand for importing petrochemical oil and minimizes the expense of treating garbage. Economics, ecology, and resource conservation are the three routes to biodiesel production from spent cooking oil (Phan and Phan 2008). The biodiesel from waste cooking oil and blended it with fossil fuel at varied ratios, then tested the performance and emissions of a diesel engine using this fuel. While utilizing a B30 gasoline blend decreased emissions of hydrocarbons (HC) and carbon monoxide (CO), it increased

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emissions of nitrogen oxides (NOx). WCO biodiesel blends were found to negatively affect the performance of the turbocharged diesel engine (Senthur Prabu et al 2017).

Combustion and emission studies revealed a higher fuel consumption compared to exhaust emissions, although WCO use typically resulted in lower carbon and hydrocarbon emissions, and the nitrogen oxide generated by WCO was lower than by diesel fuel in most operational conditions (An et al 2013). The addition of WCO biodiesel to diesel blends increased the exhaust gas temperatures of these mixtures. Because spent cooking oil and its derivatives have a lower heating value, they require more fuel overall to provide the same amount of heat. As the biodiesel content of a blend increases, efficiency decreases. With a diesel engine, the researcher conducted an experimental investigation of combustion using WCO at values of 5% and 10%. Emissions of both smoke and hydrocarbons were found to have decreased, while emissions of nitrogen oxide increased. The fatty acid content of used cooking oils from different restaurants in the same area was found to vary, leading them to anticipate that biodiesel would also have a wide range of compositions depending on its source (Can 2014). Using diesel blended with WCO biodiesel, analyzed the effect on emissions from a diesel engine operating at a constant speed. Researchers found that using biodiesel reduced HC and CO emissions but increased NOx levels (Cheung et al 2015; Man et al 2015).

Di-ethyl ether was blended with jatropha biodiesel to boost ignition performance. For DEE10 and DEE20 mixes, it was found during performance testing that fuel consumption increased along with thermal efficiency (Raja et al 2022). It was attempted to optimize the system with the load condition and fuel as the restrictions. The usage of mahua methyl ester and diethyl ether as additives in a diesel engine was studied, along with the resulting engine exploration and exhaust emissions (Rao and Reddi 2020). When compared to the other fuels tested, a diesel-waste-plastic blend containing 10% DEE performed the best under the vast majority of engine loads. Changing the fuel type had no effect on the combustion time (Selvam et al 2022). For the purpose of evaluating bio seed cashew nut shell biodiesel, the cetane agitator dimethyl ether has been added to the engine research and emission requirements. They analyzed the combustion process and measured the levels of emissions produced by a diesel engine. Better thermal efficiency, lower fuel use, and fewer exhaust emissions were indicators of the boost in performance (Joshi and Thipse 2021). The oxygenated addition to assess the engine and emission analysis of plastic waste oil. The results indicated a marginal reduction in emissions of carbon, hydrocarbons, and nitrogen oxides (Sambandam Padmanabhan et al 2022).

There is a positive correlation between load, compression ratio, waste plastic oil, and ethanol in diesel, all of which contribute to greater thermal efficiency and fewer harmful emissions. ANOVA and multivariate analysis found the sweet spot for engine load, compression ratio, and fuel blend, which improved performance and reduced emissions (Das et al 2020). The thermal efficiency of braking and emissions were improved by using a compression ratio of 18.1, along with a blend of diesel fuel containing 20% WPO and 20% ethanol. There were three different amounts of WPO in the tertiary fuel mix, along with ethanol (Bhargavi et al 2022). Optimization of performance, emissions, and fuel economy were studied using a Full Factorial Design. DoE-based optimization using a three-factor full factorial trial design was utilised to achieve optimal pollution reduction and fuel economy. Statistically significant surface contour plots for carbon monoxide, hydrogen chloride, and fuel economy (S Padmanabhan et al 2022).

The purpose of this research is to examine the impact of a 20% and 40% diethyl ether ratio on biodiesel blends made from waste cooking oil and regular diesel. A single-cylinder diesel engine is analyzed for performance and emissions under different loads. For mixes of WCO and DEE, the best results in terms of fuel consumption, hydrocarbon emission, and carbon monoxide emission were achieved by the use of the experimental method "Full Factorial Design".

2. Materials and Methods

Using vegetable oils in diesel engines has led to operational and long-term reliability problems. They may be because vegetable oils are more dense and don't burn as easily. By transesterifying vegetable oils, it was possible to make them less thick while also getting rid of problems with their use and durability. The use of used cooking oils as a source of biodiesel is becoming more and more cost-effective. Used cooking oil might be a cheaper bio resource than edible vegetable oils because it doesn't affect the growth of food crops in any way. Waste cooking oil biodiesel, like biofuels made from seeds, is thicker and denser than regular diesel. However, it can meet the current fuel base requirements (Man et al 2015; Elnajjar et al 2022).

Diethyl ether was generally used as oxygenated additives in CI engines and was described as being very helpful in reducing the viscosity and density of pure biodiesel fuels because they have lower viscosity and density values than conventional diesel fuel. The lower viscosity of oxygenated additives as compared to diesel, allows for more efficient atomization of the fuel injected into the cylinders and better mixing with the surrounding air when oxygenated additives are combined with diesel. A significant amount of latent heat of evaporation exists in alcohol, which means that utilising oxygenated additives in a diesel engine by blending them with diesel is possible (Raja et al 2022). The most efficient technique for purifying biodiesel is liquid-liquid extraction using glycerol at 15 wt% and two-step contact. When evaluating different purification techniques, the after-treatment of the purifying agents is crucial. Soap, methanol, and glycerol can be successfully removed by all of the purification techniques that were examined. Density, kinematic viscosity, and glyceride concentration were unaffected by any of the approaches (Berrios et al 2011).

Some oxygenated additions can be used to improve the quality of biodiesel so that it is more comparable to diesel. For instance, biodiesel's viscosity is noticeably higher than that of diesel. Fuel injection efficiency can be decreased if the fuel's viscosity is increased, as this can increase the droplet size of the atomized fuel. Conversely, alcohols have a low viscosity. Alcohols are added to diesel-biodiesel blends to reduce the fuel's viscosity and bring it closer to that of diesel (S Padmanabhan et al 2022). Renewable-produced diethyl ether is an oxygenated renewable fuel that may be derived from biomass and is used as an ingredient in ethanol. Through a process called transesterification, any type of vegetable oil can be converted into biodiesel. Vegetable oil, along with an alcohol such as methanol or ethanol and a catalyst, undergoes a chemical reaction known as transesterification (Amenaghawon et al 2022). Vegetable oil undergoes a chemical process that breaks it down into smaller molecules. Biodiesel begins as triglycerides, which are transformed into alkyl esters. If methanol is employed, the resulting product is a methyl ester, while ethanol yields an ethyl ester. The chemical makeup of these two biodiesel fuels is different. Glycerin is produced during the chemical process and must be separated from biodiesel before it can be used. Glycerin's phase in the fluid might cause it to float to the surface or sink to the bottom. Not only is that, but the process of separating it using centrifuges is known as "transesterification." Biodiesel, the product of transesterification, has a lower viscosity than regular diesel fuel and can therefore be used in diesel engines (Suzihaque et al 2022). The properties of waste cooking biodiesel and diethyl ether are tabulated in Table 1.

Table 1 Properties of WCO and DEE.

Sl.No	Fuel Property	Diesel	WCO	DEE
1	Density, at 15 °C (g/m^3)	0.843	0.882	0.710
2	Viscosity, at 40 °C (cSt)	2.45	4.99	0.23
3	Lowest heating Value, (MJ/kg)	42.31	35.82	33.9
4	Flash Point, (°C)	61	162	-40
5	Oxygen (wt %)	0	11	21
6	Carbon (wt %)	86	72	64
7	Hydrogen (wt %)	13	10	13.5
8	Cetane Index	54	47	125

2.1. Experimental Details

Figure 1 shows a single-cylinder, constant-speed, direct-injection engine was used to test waste cooking oil biodiesel blends. The speed of the diesel engine is not affected by either the load or the percentage of biodiesel mix that is being used. The engine was connected to an eddy current dynamometer, which allowed for the loads to be varied anywhere from 0% to 100% of its maximum capacity. According to the 4.4 kW power output of the engine, the load was increased by 25%, 50%, 75%, and 100% for each of the mixes that were put through the testing process. In order to make manual adjustments to the engine loads, an eddy current dynamometer, which measures the flow of current, is utilized. During this investigation, the rate of airflow was studied with the help of a calibrated burette, and the rate of fuel flow was determined with the help of a calibrated orifice that was mounted on an air drum. The fuel flow was measured using two different fuel tanks, one filled with regular diesel and the other with biodiesel that had been esterified. Both fuel tanks were used for the measurement. The testing apparatus was outfitted with AVL software, which enabled the collection of a variety of readings and results even while the machine was functioning normally. Table 2 represents the experimental measurements, instruments, and parameters.

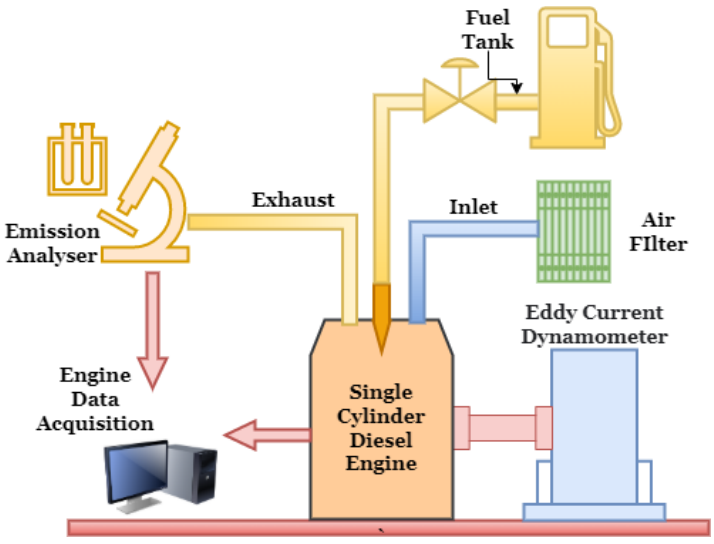

Figure 1 Experimental engine setup.

Table 2 Experimental measurement and its parameters.

Sl. No	Measurement	Range	Accuracy	Percentage of Uncertainty	Instrument
1	Hydrocarbon	0 to 10000 ppm	± 5 ppm	± 0.15	AVL Gas Analyser
2	Carbon monoxide	0 to 20%	± 0.05%	± 0.15	AVL Gas Analyser
3	Nitrogen Oxides	0 to 10000 ppm	± 20 ppm	± 0.15	AVL Gas Analyser
4	Engine Power	0.1 to 4.4kW	± 0.05 kW	± 0.50	Load cell
5	Crank Speed	0- 10000 rpm	± 10 rpm	± 0.50	Digital tachometer
6	Fuel Quantity	0-50 cm^3	± 0.1 cm^3	± 0.50	Burette Measurement

This study focuses on energy recovery from waste cooking oil as the alternative fuel source via the waste utilization approach. In this study, a novel fuel blending method used palm oil and sunflower oil in an equal ratio as the source of waste cooking oil extraction to use as testing fuel. Waste cooking oil obtained from the transesterification process of vegetable oil was blended with diesel at different ratios of 20% and 40% on a volume basis, along with oxygenated additives of diethyl ether. The biodiesel fuel, named D70W20DEE10, is formed by the blends of 20% Waste Cooking Oil biodiesel, 10% diethyl ether on a volume basis mixed with pure diesel of 70%. The biodiesel fuel blends prepared as D50W40DEE10 (50% diesel + 40% WCO+ 10% DEE), D60W20DEE20 (60% diesel + 20% WCO+ 20% DEE), and D40W40DEE20 (40% diesel + 40% WCO+ 20% DEE).

3. Results and discussion

3.1 Performance Characterizes

It can be observed in Figure 2 that the Brake Thermal Efficiency (BTE) had an effect on the engine's maximum output power. At maximum load condition, the BTE of D70W20DEE10, D50W40DEE10, D60W20DEE20, and D40W40DEE20 were 28.88 %, 28.18 %, 30.54 %, and 28.66 %, respectively. The thermal brake efficiency of D60W20DEE20 was found to be about 5.2 % higher than that of pure diesel when tested under maximum load conditions. A higher oxygen concentration in DEE means that it will burn more efficiently, resulting in increased thermal performance (Raja et al 2022). Because of the higher viscosity and resulting lower combustion rate caused by the high content of DEE in the mix, the BTE is lower than that of WCO40.

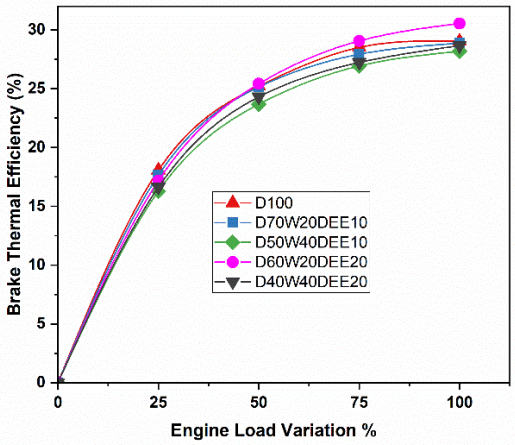

Figure 2 Effect of DEE on WCO's brake thermal efficiency.

It was determined that the rise in specific fuel consumption (SFC) was due to the increase in injected fuel that occurred concurrently with the increase in load. As can be seen in Figure 3, the SFC drops with increasing engine load and DEE ratios. Both D50W40DEE10 and D40W60DEE20 have greater SFC values than diesel. The more oil mixes that are used in place of diesel oil to get the same output power, the more fuel is consumed. Consequently, the fuel injected into the combustion chamber had smaller droplet sizes, less fuel penetration, incorrect fuel-air mixing, and decreased combustion efficiency because of the lower viscosities of the oil mixes (Hwang et al 2016). Blends of D70W20DEE10 and D60W20DEE20 achieved SFC reductions of 8.75% and 15%, respectively, compared to diesel, while blends of WCO40 achieved SFC reductions of 6.25 percent and 12.5%, respectively, compared to diesel.

3.2 Emission Characteristics

CO emissions are shown as a function of engine load in Figure 4 for blends of D70W20DEE10, D50W40DEE10, D60W20DEE20, and D40W40DEE20. Reducing the equivalency ratio and increasing the in-cylinder temperatures of WCO20s results in fewer CO emissions. Due to the rich fuel mixture at WCO40 and DEE blends, large levels of CO were reported to be

generated during both start and full load conditions. From low to half load, CO2 emissions decrease for all WCO blends before increasing dramatically from there to full power. At varying loads, the D60W20DEE20 reduced carbon monoxide emissions by 7–9 percent compared to the diesel engine. Less carbon dioxide was released as a result of the lower C/H ratio. When the mix ratio was increased, carbon monoxide levels were reduced. Reduced carbon emissions can be attributed to DEE's enhanced atomization, combustion efficiency, and vaporization compared to those of pure diesel (Degfie et al 2019).

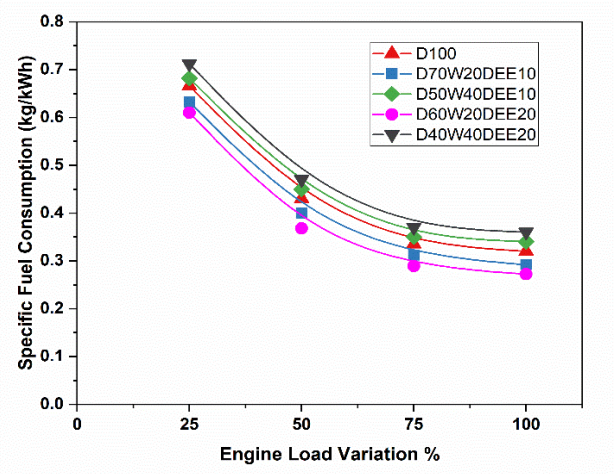

Figure 3 Effect of DEE on WCO's specific fuel consumption.

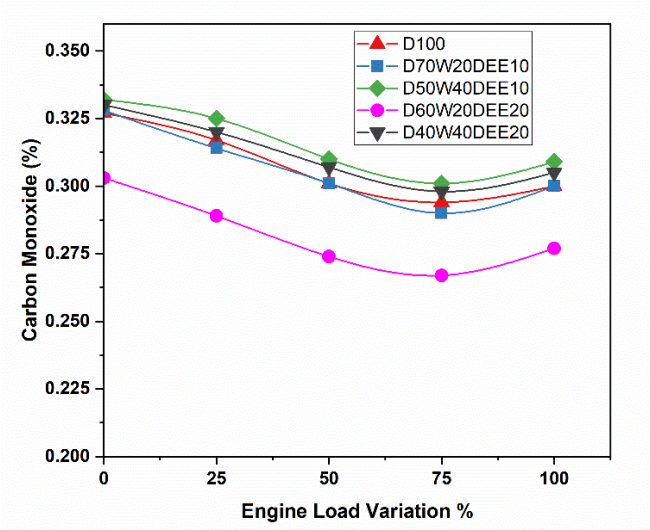

Figure 4 Effect of DEE on WCO's Carbon Monoxide emission.

Unburned hydrocarbon emissions and engine load for WCO and DEE blends are shown in Figure 5. A higher volume of fuel being injected into the engine is responsible for the increase in HC emissions seen in response to increased engine load at all blending ratios. Mixes of D70W20DEE10 and D60W20DEE20 reduced HC emissions by 2% and 9%, respectively, compared to pure diesel, while WCO40 blends attained 3% and 12% increased hydrocarbon emissions compared to diesel. This is because the flame quench has increased as cylinder temperatures have risen. However, the extremely low viscosity of the oil, which caused smaller droplet sizes and impeded diffusion, contributed to an increase in HC concentrations as the oil blending ratio was raised (Sambandam et al 2022). As a result of the poor fuel-air mixture, combustion efficiency dropped, and HC emissions rose. Increased HC emissions and decreased vaporization and spray penetration were the results of the WCO40 mixes' higher viscosity (Erchamo et al 2021).

As shown in Figure 6, the quantities of nitrogen oxides in oil mixtures changed in response to varying engine loads. Increased engine load was attributed to the rise in NOx emissions as a result of increased fuel consumption. The NOx emissions of D70W20DEE10, D50W40DEE10, and D60W20DEE20 are 4.2%, 5.5%, 6.8%, and 13.4% higher than those of diesel, respectively. Combustion temperature, time, fuel nitrogen content, and air oxygen content all play a role in the amount of nitrogen oxides (NOx) released into the atmosphere. Some of the variables that affect the total amount of nitrogen oxides produced are the temperature of the combustion chamber, the oxygen content, the amount of supplementary air, and the duration of the combustion process. The principal source of the pollutant is NOx, which is created when oxygen and nitrogen react. The combustion temperature rises, and more NOx is produced at higher oxygen concentrations (Hwang et al 2016).

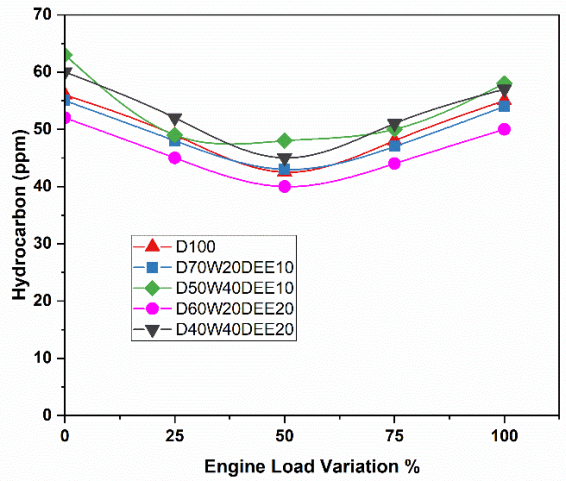

Figure 5 Effect of DEE on WCO's hydrocarbon emission

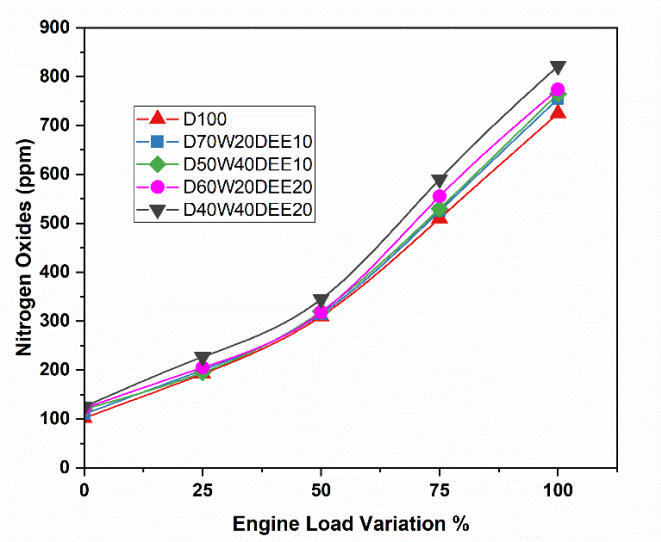

Figure 6 Effect of DEE on WCO's Nitrogen Oxide Emission.

3.3 Optimization of WCO and DEE blend ratio on Emission

Design of Experiment (DOE) is frequently utilized in process improvement to provide the most exhaustive solution to a solvable issue. In contrast to the conventional approach, this strategy employs statistical data acquired from a small number of trials to predict the knowledge and outcomes of a complicated and multivariable process that is now underway. DOE is the most prevalent numerical method for optimizing results compared to all other research methods. Full Factorial Design (FFD) is an analytical and systematic strategy for evaluating the key effects and interactions in research projects (Padmanabhan et al 2022; Ganesan et al 2022). A number of process parameters and their corresponding levels were required to develop a complete factorial model for the study investigation. In this study, the impact of WCO and DEE on fuel consumption and CO and HC emissions was examined.

The DEE has a positive effect on fuel consumption and emissions, with the lowest value attained at 20% DEE mix. This is considered to be associated to a faster combustion rate due to a higher oxygen concentration in the DEE. Additionally, because WCO has a greater viscosity, emissions have increased when the blend ratio has been increased, which has led to a decrease in the burning effect. This is because the higher viscosity of WCO is a result of the higher viscosity of WCO. There is a correlation between an increase in the DEE ratio and a decrease in emissions, with the lowest levels of carbon monoxide and hydrocarbon emissions formed at 20% of the DEE ratio. This is primarily because of the higher rate of combustion that occurs at this ratio, which is the most significant factor. Because of the more oxygenated mixture that is formed as a result of using a 20% blend of WCO and DEE, the amount of CO and HC that is produced is decreased (Bhargavi et al 2022). This is made possible by the fact that the combustion process is aided in its completion by using the WCO and DEE. Because WCO fuel has a higher viscosity than conventional fossil fuel, the quantity of hazardous pollutants discharged increases as the WCO ratio increases. This phenomenon arises as a result of faulty fuel combination and spray creation, which leads to incomplete combustion as

the blend ratio increases. This phenomenon is caused by poor fuel combination and spray formation. According to the contour plots (Figures 7, 8, and 9), the most significant influence on the ability of the engine to operate with the fewest possible emissions and the most efficient use of fuel is exerted by the DEE blend at its highest concentration, while the minimum blend of WCO has the opposite effect.

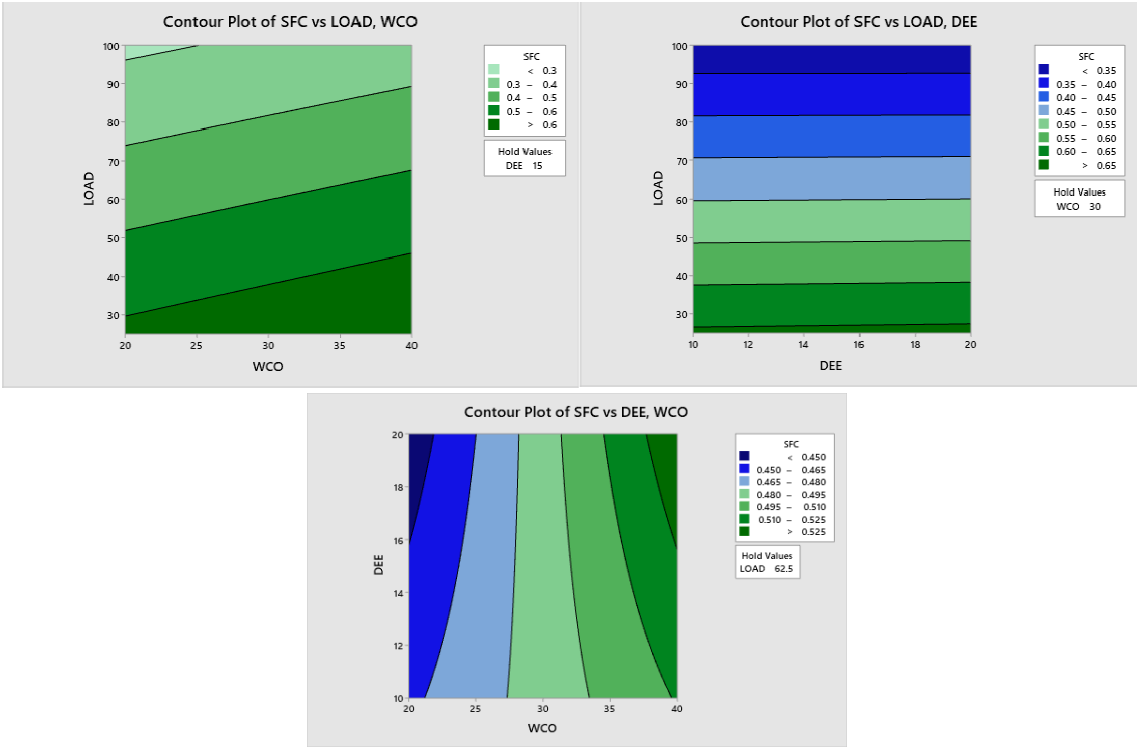

Figure 7 Influence of WCO and DEE blend on SFC

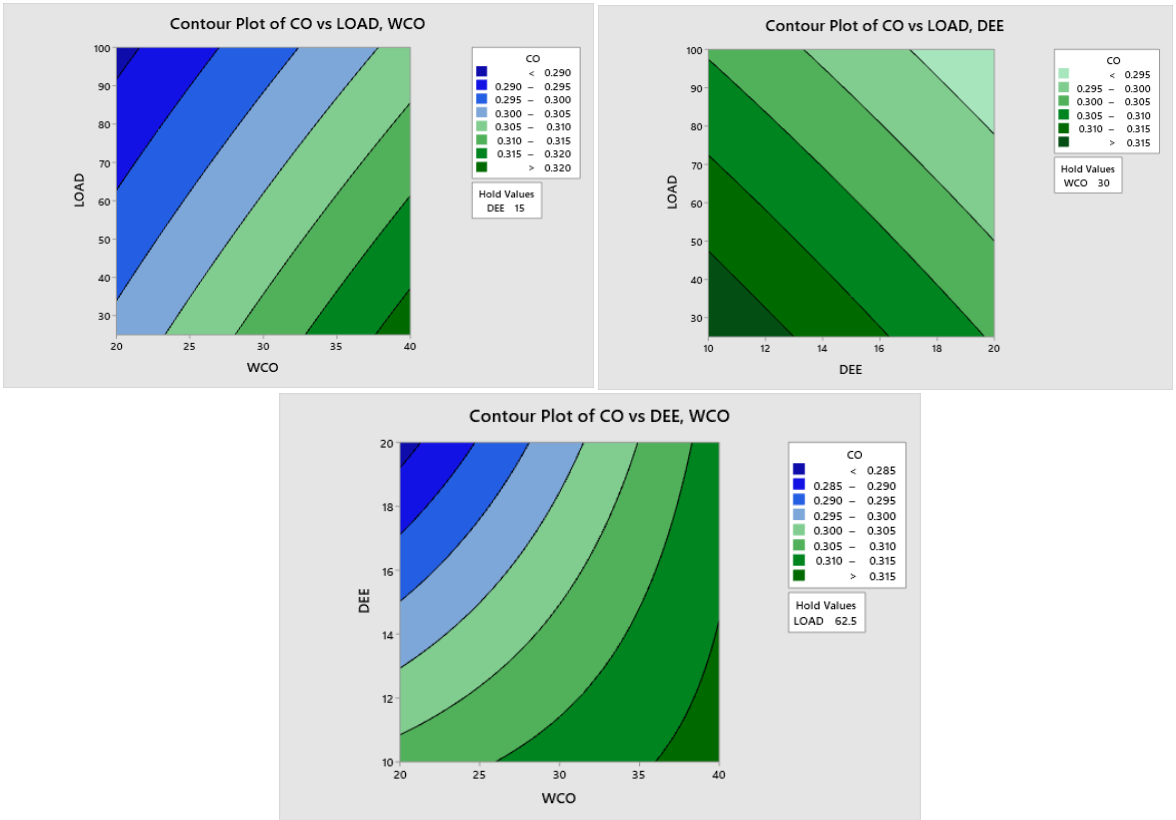

Figure 8 Influence of WCO and DEE blend on CO emission

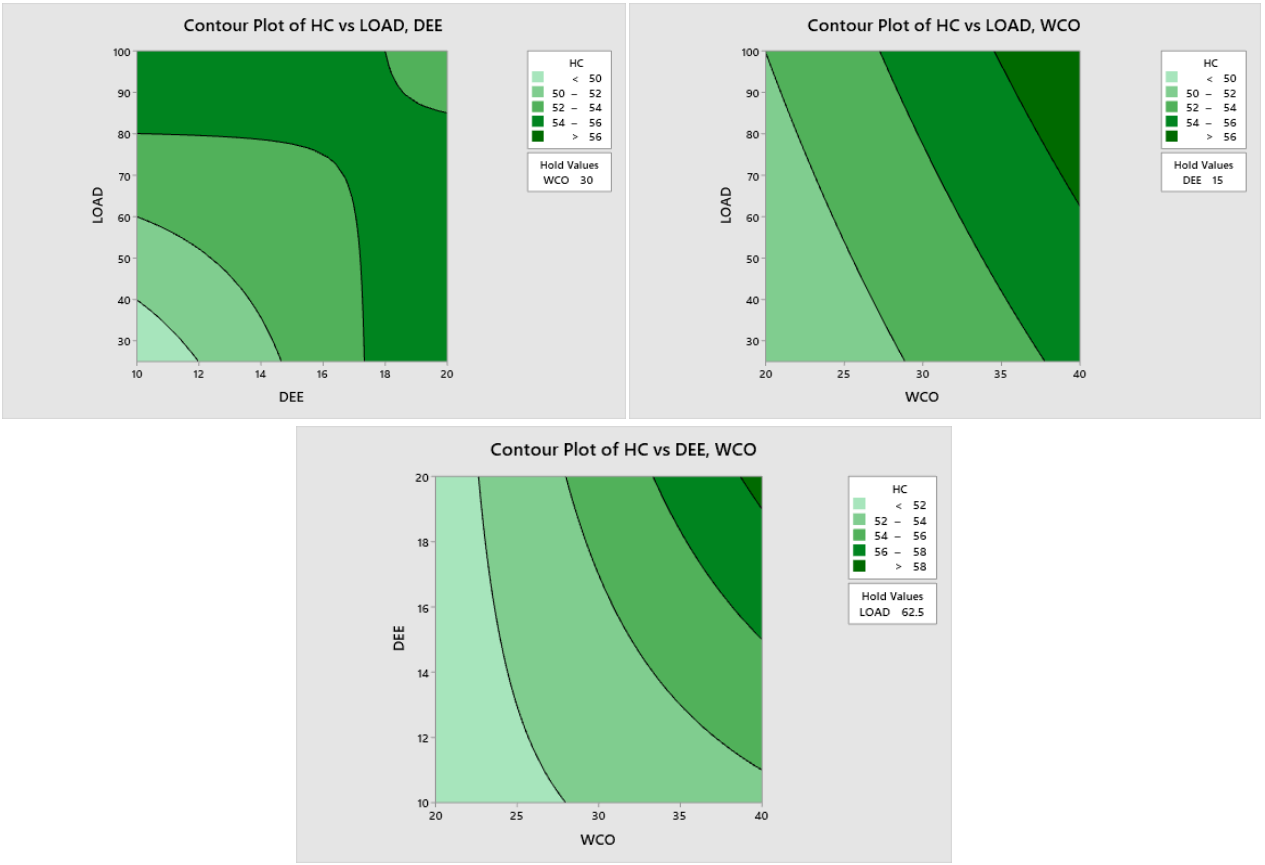

Figure 9 Influence of WCO and DEE blend on HC emission

3.4 Response Optimization of SFC, CO, and HC

Response optimization examines the connection between different types of input factors and the optimal combination of those parameters in order to enhance the quality of an answer or a set of responses. For each possible combination of input variables, the response optimizer feature of statistical analysis software generates an optimization graphic that displays the optimal solution (Sambandam Padmanabhan et al 2022). The visual used for optimization may or may not have any sort of interactivity. Changing the values of the input variables can be a useful strategy for enhancing an optimization problem.

The response optimizer Table 3 and Figure 10 indicate that the lowest blend ratio of WCO at the highest DEE additive is obtained to be best for attaining low exhaust emissions and the lowest fuel consumption under maximum loading circumstances, and this conclusion is supported by the results. At these blend ratios, total combustion occurs as a result of a faster combustion rate and a higher oxygenated mixture, resulting in incomplete combustion. All reactions will improve if the WCO/DEE combination is increased. To a much lesser extent than CO and HC emissions, however, was the impact felt on SFC. Therefore, the best settings of the WCO and DEE mix were at the minimal levels in the experiment when reducing the composite's appeal. Based on these findings, researchers may want to try out other blend ratios of WCO and DEE to see if they improve engine performance. Increasing the load on the engine reduces SFC and CO emissions while slightly increasing HC emissions. During the testing, the maximum load condition yielded the best SFC and CO settings. This finding hints that attempting to boost the engine's load might increase its efficiency.The best conditions for achieving these results are when the engine is filled with fuel and a combination of 20 % WCO and DEE with the diesel fuel blend, respectively. When operating at maximum load, the ideal minimal emissions generated by a 20 % WCO and DEE mix are CO at 0.277 % and HC at 50 parts per million. Under identical operating conditions, the lowest feasible fuel usage of 0.2720 kg/kWh was achieved.

Table 3 Response Optimized results of HC, CO and SFC.

Solution	WCO	DEE	LOAD	HC Fit	CO Fit	SFC Fit	Composite Desirability
1	20.0000	20.0000	100	50.0000	0.277000	0.272000	0.980144

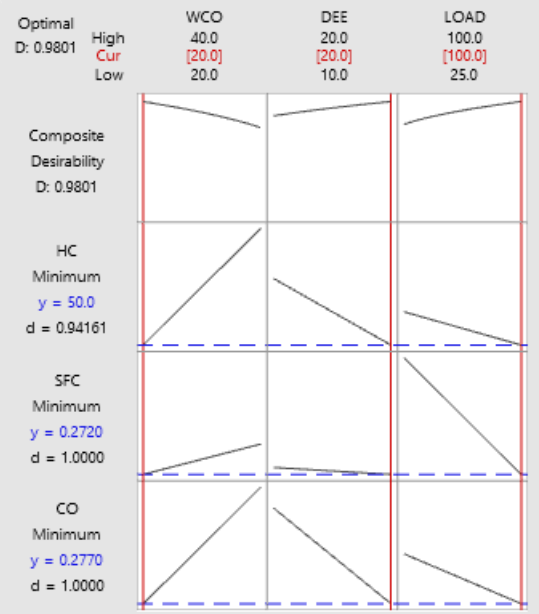

Figure 10 Optimization plot for HC, CO, and SFC

4. Conclusions

Biodiesel has recently acquired appeal as a way to minimize pollution from the combustion of fossil fuels. Waste cooking oil is the best material for biodiesel production because it is inexpensive and reduces waste. It is viable to use oxygenated fuels to reduce diesel emissions. In this investigation, a diesel engine operated with varying levels of diethyl ether additives and biodiesel made from waste cooking oil. The following observations were made during the investigation of waste cooking oil for biodiesel:

Under maximum load conditions, it was determined that the thermal efficiency of D60W20DEE20 brakes was approximately 5.2% higher than that of pure diesel. D70W20DEE10 and D60W20DEE20 blends obtained 8.75% and 15% lower SFC than diesel, respectively, whereas WCO40 blends achieved 6.25 and 12.5% higher fuel consumption than diesel, respectively. D70W20DEE10 and D60W20DEE20 blends reduced HC emissions by 2% and 9%, respectively, compared to diesel; however, WCO40 blends increased hydrocarbon emissions compared to diesel.

Compared to the diesel engine, the D60W20DEE20 had lower carbon monoxide emissions by between 7% and 9%, depending on the load. D70W20DEE10, D50W40DEE10, and D60W20DEE20 have NOx emissions that are 4.2%, 5.5%, 6.8%, and 13.4% greater than diesel, respectively. When the engine is fully loaded and a 20% blend of WCO and DEE is added to diesel fuel, the best results are obtained with the DEE. At maximum load, the optimal minimal CO and HC emissions from a 20% WCO and DEE blend are 0.277% and 50 ppm, respectively. At the same operating conditions, the lowest achievable fuel usage of 0.2720 kg/kWh was attained. A bio-economy requires the recycling of organic materials into valuable fuel and materials. Integration of recycling and bioconversion for enhanced process performance is also assessed. The goal of this work is to make it easier to recycle bio-waste for use in closed-loop systems. Biofuels reduce global warming by using the planet's carbon cycle. Biofuel reduces greenhouse gas emissions by one gallon per gallon.

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

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References

Amenaghawon AN, Obahiagbon K, Isesele V, Usman F (2022) Optimized biodiesel production from waste cooking oil using a functionalized bio-based heterogeneous catalyst. Clean Eng Technol 8:100501. DOI: 10.1016/j.clet.2022.100501

An H, Yang WM, Maghbouli A, Li J, Chou SK, Chua KJ (2013) Performance, combustion and emission characteristics of biodiesel derived from waste cooking oils. Appl Energy 112:493–499. DOI: 10.1016/j.apenergy.2012.12.044

Berrios M, Martín MA, Chica AF, Martín A (2011) Purification of biodiesel from used cooking oils. Appl Energy 88:3625–3631. DOI: 10.1016/j.apenergy.2011.04.060

Bhargavi M, Vinod Kumar T, Ali Azmath Shaik R, Kishore Kanna S, Padmanabhan S (2022) Effective utilization and optimization of waste plastic oil with ethanol additive in diesel engine using full factorial design. Mater Today Proc 52:930–936. DOI: 10.1016/j.matpr.2021.10.310

Can Ö (2014) Combustion characteristics, performance and exhaust emissions of a diesel engine fueled with a waste cooking oil biodiesel mixture. Energy Convers Manag 87:676–686. DOI: 10.1016/j.enconman.2014.07.066

Cheung CS, Man XJ, Fong KW, Tsang OK (2015) Effect of Waste Cooking Oil Biodiesel on the Emissions of a Diesel Engine. Energy Procedia 66:93–96. DOI: 10.1016/j.egypro.2015.02.050

Das AK, Padhi MR, Hansdah D, Panda AK (2020) Optimization of Engine Parameters and Ethanol Fuel Additive of a Diesel Engine Fuelled with Waste Plastic Oil Blended Diesel. Process Integr Optim Sustain 4:465–479. DOI: 10.1007/s41660-020-00134-7

Degfie TA, Mamo TT, Mekonnen YS (2019) Optimized Biodiesel Production from Waste Cooking Oil (WCO) using Calcium Oxide (CaO) Nano-catalyst. Sci Rep 9:18982. DOI: 10.1038/s41598-019-55403-4

Elnajjar E, Al-Omari SAB, Selim MYE, Purayil STP (2022) CI engine performance and emissions with waste cooking oil biodiesel boosted with hydrogen supplement under different load and engine parameters. Alexandria Eng J 61(6):4793–4805. DOI: 10.1016/j.aej.2021.10.039

Erchamo YS, Mamo TT, Workneh GA, Mekonnen YS (2021) Improved biodiesel production from waste cooking oil with mixed methanol–ethanol using enhanced eggshell-derived CaO nano-catalyst. Sci Rep 11(1):6708. DOI: 10.1038/s41598-021-86062-z

Ganesan S, Padmanabhan S, Hemanandh J, Venkatesan SP (2022) Influence of substrate temperature on coated engine piston head using multi-response optimisation techniques. Int J Ambient Energy 43(1):610–617. DOI: 10.1080/01430750.2019.1653988

Hwang J, Bae C, Gupta T (2016) Application of waste cooking oil (WCO) biodiesel in a compression ignition engine. Fuel 176:20–31. DOI: 10.1016/j.fuel.2016.02.058

Joshi MP, Thipse SS (2021) Combustion analysis of a compression-ignition engine fuelled with an algae biofuel blend and diethyl ether as an additive by using an artificial neural network. Biofuels 12(4):429–438. DOI: 10.1080/17597269.2018.1489675

Li M, Zheng Y, Chen Y, Zhu X (2014) Biodiesel production from waste cooking oil using a heterogeneous catalyst from pyrolyzed rice husk. Bioresour Technol . 154:345–348. DOI: 10.1016/j.biortech.2013.12.070

Man XJ, Cheung CS, Ning Z (2015) Effect of Diesel Engine Operating Conditions on the Particulate Size, Nanostructure and Oxidation Properties when Using Wasting Cooking Oil Biodiesel. Energy Procedia 66:37–40. DOI: 10.1016/j.egypro.2015.02.020

Padmanabhan Sambandam, Giridharan K, Stalin B, Kumaran S, Kavimani V, Nagaprasad N, Tesfaye Jule L, Krishnaraj R (2022) Energy recovery of waste plastics into diesel fuel with ethanol and ethoxy ethyl acetate additives on circular economy strategy. Sci Rep 12(1):5330. DOI: 10.1038/s41598-022-09148-2

Padmanabhan S, Kumar TV, Giridharan K, Stalin B, Nagaprasad N, Jule LT, Ramaswamy K (2022) An analysis of environment effect on ethanol blends with plastic fuel and blend optimization using a full factorial design. Sci Rep 12(1):21719. DOI: 10.1038/s41598-022-26046-9

Panwar NL, Kaushik SC, Kothari S (2011) Role of renewable energy sources in environmental protection: A review. Renew Sustain Energy Rev 15(3):1513–1524. DOI: 10.1016/j.rser.2010.11.037

Phan AN, Phan TM (2008) Biodiesel production from waste cooking oils. Fuel 87(17):3490–3496. DOI: 10.1016/j.fuel.2008.07.008

Raja K, Srinivasa Raman V, Parthasarathi R, Ranjitkumar K, Mohanavel V (2022) Performance analysis of DEE-Biodiesel blends in diesel engine. Int J Ambient Energy 43(1):1016–1020. DOI: 10.1080/01430750.2019.1670262

Rao KP, Reddi V (2020) Parametric optimization for performance and emissions of DI diesel engine with Mahua biodiesel along with Diethyl ether as an additive. Biofuels 11(1):37–47. DOI: 10.1080/17597269.2017.1338126

Sambandam P, Murugesan P, Thangaraj VK, Vadivel M, Rajaraman M, Subbiah G (2022) Environmental impact of waste plastic pyrolysis oil on insulated piston diesel engine with methoxyethyl acetate additive. Pet Sci Technol 1–18. DOI: 10.1080/10916466.2022.2092498

Selvam MAJ, Sambandam P, Sujeesh KJ (2022) Investigation of performance and emission characteristics of single-cylinder DI diesel engine with plastic pyrolysis oil and diethyl ether blends. Int J Ambient Energy 43(1):3810–3814. DOI: 10.1080/01430750.2020.1860127

Senthur Prabu S, Asokan MA, Roy R, Francis S, Sreelekh MK (2017) Performance, combustion and emission characteristics of diesel engine fuelled with waste cooking oil bio-diesel/diesel blends with additives. Energy 122:638–648. DOI: 10.1016/j.energy.2017.01.119

Suzihaque MUH, Alwi H, Kalthum Ibrahim U, Abdullah S, Haron N (2022) Biodiesel production from waste cooking oil: A brief review. Mater Today Proc 63:S490-S495. DOI: 10.1016/j.matpr.2022.04.527

Venkatesh AP, Muniyappan M, Joel C, Padmanabhan S (2021) Investigation on the effect of nanofluid on performance behaviour of a waste cooking oil on a small diesel engine. Int J Ambient Energy 42(5):540–545. DOI: 10.1080/01430750.2018.1557554

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The Chinese Resistance to Land Rights Discrimination in Indonesia

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Abstract Ethnic Chinese is the largest ethnic minority in Indonesia. However, ethnic Chinese is not entirely accepted by Indonesian society. For instance, ethnic Chinese experienced discrimination through the 1975 instruction, which prohibited land ownership in the only special region of Indonesia, namely Yogyakarta. This article aims to trace the ethnic Chinese response to the 1975 Instruction. By employing the historical method with a multidimensional social sciences approach. This research shows that historically ethnic Chinese who have experienced discrimination in land ownership rights in Yogyakarta since 1975 only started to carry out resistance in 1998. Resistance began to emerge and grew with increasing escalation due to factors in the political culture conditions that occurred in Indonesia generally and Yogyakarta especially. The resistance carried out divided into individuals and groups. However, both are categorized as open resistance. In the end, the Indonesian government needs to take serious steps to address the issue of racial discrimination in land rights before it escalates into conflict.

Keywords: minority, 1975 instruction, Yogyakarta, Granad, Forpeta, post-authoritarian

1. Introduction

Indonesia, as a nation, has become one of the most multicultural societies in the world. The multicultural society in Indonesia comes from various ethnic groups that live in the territory of Indonesia and build Indonesia as a nation. Central Agency on Statistics of Indonesia (2010) noted that Indonesia consists of more than 1,300 ethnic groups. However, of the many ethnic groups in Indonesia, there are ethnic ones that are considered indigenous and some are considered non-indigenous. One of the ethnic groups called non-indigenous is ethnic Chinese. However, in the history of Indonesia, ethnic Chinese has not been fully accepted as a member of the nation (Suryadinata 1997). Such circumstances make ethnic Chinese vulnerable to becoming targets of discrimination.

Debebe et al (2022) state that the interpretation of historical phenomena plays a big role in a nation. Historically as studies conducted by many scholars, ethnic Chinese have gone through many discriminatory historical phenomena in the frame of Indonesia as a nation. During the colonial period, ethnic Chinese received a negative stigma from society due to their role as overseers during the cultivation system period, which was considered to be miserable for the indigenous people (Carey 1984). In the post-colonial, ethnic Chinese in the Old Order era under President Soekarno experienced discriminatory actions in the field of sports through affirmative policies for natives, so that ethnic Chinese did not dominate in the number of national athletes (Tanasaldy and Palmer 2019). The next era under President Soeharto (known as the New Order era) forced ethnic Chinese by the dominant discourse to assimilate Indonesian culture by completely abandoning their original identity with the aim of absorbing ethnic Chinese as this minority into the national body (Hoon 2006). The situation changed when entering the Reform era after the 1998 riots in Indonesia. Subsequent presidents introduced policies aimed at easing legal restrictions on ethnic Chinese in Indonesia (Turner and Allen 2007). Nevertheless, in fact, there is still discrimination against ethnic Chinese in the era of modern Indonesia.

As the previous paragraph already suggested, there have been many studies on discrimination against ethnic Chinese in Indonesia. Yet, one issue that is almost absent is their response to discrimination. One of the discriminations received by ethnic Chinese in modern Indonesia is in their only special region, namely Yogyakarta. Yogyakarta, as a Special Region of Indonesia, granted specialness rights to a land authority. Ethnic Chinese have been prohibited from having the right to land ownership in Indonesia since 1975 (Tania and Satriawan 2021). The prohibition is stated in the Instruction of the Head of the Special Region of Yogyakarta Number K.898/I/A/1975, more familiarly referred to as the 1975 Instruction. Based on the rule, ethnic Chinese can only obtain building rights on Yogyakarta lands. The regulation is one of the implementations of separate rights granted by the central government in the land sector only to the special region of Yogyakarta.

The objective of this study is to trace the historical records of Chinese resistance as a response to the discrimination on land rights in Yogyakarta as the only special region of Indonesia. The main question is how is the dynamics of Chinese resistance

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as a response to discrimination on land ownership rights in Yogyakarta since 1975. This study aims to reconstruct the history of ethnic Chinese resistance in Yogyakarta within 25 years, from 1975 to 2020. This research becomes important because it sees the dynamics of the multicultural and plural society in Yogyakarta so that it can be a reflection of Indonesia in an effort to achieve national harmonization. Moreover, it is a campaign about respecting human rights, pluralism, and multiculturalism in the world in this era of globalization.

Figure 1 Several ethnic Chinese held demonstrations to protest against discrimination in land rights. Source: iNews Yogya (2018).

2. Materials and Methods

This study is written based on employing the historical research method, which has four operational steps: heuristics, source criticism, interpretation, and historiography (Gottschalk 1981). The data used in this study consists of historical sources derived from reports and news with the content of the results of interviews with related informants and archives as primary sources and journals and books as secondary sources to support the argumentation in interpretation. This research seeks to use the model of Sartono Kartodirdjo's (1992) historical methods with a multidimensional social science approach. The main concept used to help the analysis is James C. Scott's (1985) concept of open resistance, which he defines as organized, systematic, cooperative, unselfish, and revolutionary it also embodies intentions that negate the basis of domination. Resistance can also be in the form of various efforts made to survive and find a decent living (Scott 1990).

3. Results and discussion

3.1 Obey in Silence (1975-1998)

The 1975 Instruction, as the basic regulation for ownership rights to land in Yogyakarta, was interpreted by the government as part of its regional specialness. Although, it intends to implement affirmative action, however in its implementation, the 1975 Instruction turn on full of inconsistency that occurred in its technical application; it actually made discrimination that added to the dynamics of land affairs in Yogyakarta (Mustajab 2022). However, the specialness and central positions after being considered to play a big role in Indonesian independence, there is a distinctive pattern that is closely related to Yogyakarta.

As an ex-self-government (lit. *ex-swapraja*), Yogyakarta remains strong in its feudal cultural influence, though it has joined Indonesia as a nation and thus adopted a democratic republic in its system of government. Hamengkubuwono IX and Pakualam VIII, as local leaders, therefore automatically served as governor and vice governor had considered revolutionary figures and contributed greatly to the survival of Yogyakarta and Indonesia when they achieved and maintained independence from the Netherlands in 1945 in a conducive and restrained atmosphere. Even though they have joined Indonesia, Hamengkubuwana IX and Pakualam VIII remain as traditional rulers and become figures who are highly obeyed, respected, and upheld by the people, and also very fanatical towards their king as a leader. The people will carry out the king's orders, whatever they may be (Sutiyah 2017).

The strong feudal culture made migrants also their descendants, such as Chinese, Arabs, Indians, and Europeans, forced to follow in respect for the leader of Yogyakarta. Thus, there is no historical record that mentions Indonesian citizens descended or commonly referred to as non-indigenous resisting the 1975 Instruction even though they have been directly discriminated against in the right to own a piece of land in Yogyakarta. In fact, government archives record Indonesian citizens of descent or non-indigenous who tried to apply for the granting of land ownership title certificates using very polite words and paying respect to the regional head of Yogyakarta in their land proposal letter still getting rejected.

Deep-rooted feudal culture in Yogyakarta resulted in no resistance to the 1975 Instruction as a discriminatory policy on land rights until the demise of Hamengkubuwono IX in 1988 and Pakualam VIII in 1998 brought about a new chapter in land affairs in Yogyakarta.

3.2 The Resistances Has Begun (1998-2020)

1998 was a new chapter for Indonesia to open new historical pages. A resistance movement called the Reformasi Movement (*Gerakan Reformasi*), which spoke out against the authoritarianism of Soeharto as the president of Indonesia, first echoed in the capital and quickly followed throughout Indonesia. In spite of Yogyakarta was also one of the arenas for the struggle of the Reform Movement, it can still be said to be quite conducive because it was under the command of Hamengkubuwono X and Pakualam VIII who expressed their support for the Reform Movement. While the Reform Movement was turbulent in 1998 and spread riots in some cities, the ethnic Chinese themselves were quite cornered nationally, but not in Yogyakarta (Park 2012).

After the reform movement succeeds in overthrowing Soeharto's authoritarianism, one of the interesting growths in Indonesian society is the increasing bravery of the people to express their interests. They are no longer silent in defeat when facing the authorities (Purwanta 2022). Yogyakarta, as part of Indonesia, cannot be separated from the impact of the Reformation Movement. For example, ethnic Chinese in Yogyakarta commence responding to land ownership discrimination that they have experienced for years. Furthermore, Pakualam VIII as a signatory of the 1975 Instruction, passed away right after the end of the 1998 Reform Movement.

2001 was the year of the first time were attempts at resistance by ethnic Chinese. Budi Setyagraha, a businessman of Chinese descent who had received land ownership rights in 1998, was later rejected for a second land ownership application. Budi Setyagraha filed a State Administrative Court (lit. *Pengadilan Tata Usaha Negara*) lawsuit on the letter of the Head of the Bantul Regency Land Office regarding the refusal to grant Ownership Rights (Kurniadi 2020). At the District Court level, Budi Setyagraha was won, arguing that the 1975 Instruction was contrary to the Indonesian Basic Agrarian Law 1960 and Presidential Decree No. 33 of 1984. Yet, The Land Office appealed, and the High Court of the State Administrative Court won the Land Office with the argument that the letter of the Head of the Land Office was merely correspondence and was not an object of the State Administrative Court's. Budi Setyagraha then filed an appeal to the Supreme Court (lit. *Mahkamah Agung*). Through Supreme Court Decision No. 281 K/TUN/2001, the appeal was not accepted on the grounds that there was no legal error in the decision of the State Administrative Court judge at the High Court level. Perceive that the sense of justice was not fulfilled, Budi Setyagraha filed a Judicial Review of the Supreme Court's decision in 2001.

Willie Sebastian became the next individual to dare to defy the practice of ethnic and racial discrimination in the field of land in Yogyakarta (Yuniar 2018). Armed with the letters he sent and received, among others, to the President on February 23, 2011, regarding the request for the revocation of the 1975 Instruction and replied to by the Letter of the Deputy for Institutional and Community Relations of the Ministry of State Secretariat of the Republic of Indonesia No. B-2774/Setneg/D-3/03/2011, Willie Sebastian complained to *KOMNAS HAM* (Indonesian National Human Rights Commission) in June 2013. On August 30, 2013, *KOMNAS HAM* took the initiative to hold a meeting with the Governor of Yogyakarta, but could only be met by the Regional Secretary of Yogyakarta. In the meeting, *KOMNAS HAM* said that the implementation of the 1975 Instruction should not be continued because it is contrary to human rights. *KOMNAS HAM* also asked the Yogyakarta's Governor to meet ethnic Chinese citizens in order to resolve the problem through a mediation facilitated by *KOMNAS HAM*. This mediation ended in a stalemate; the Governor gave no signs of willingness to meet. On 11 August 2014, *KOMNAS HAM* issued letter No. 037/R/Mediation/VIII/2014 on Recommendations Related to Discrimination of Land Rights of Citizens of Chinese Descent in Yogyakarta, to the Governor. The point is that: 1) the 1975 Instructions are contrary to the 1945 Constitution, the Basic Agrarian Law, the Citizenship Law, and the Law on the Elimination of Racial and Ethnic Discrimination; 2) The following differences in discrimination and affirmative action, for example; 3) the governor is threatened with human rights violations if he ignores or rejects the recommendations of *KOMNAS HAM*.

Willie Sebastian then wrote to the Governor and Regional People's Representative Council of Yogyakarta to implement the recommendations of *KOMNAS HAM* so as not to fall into criminal acts regulated by Law No. 40 of 2008 concerning the Elimination of Racial and Ethnic Discrimination as well as human rights violations according to Law No. 39 of 1999 concerning Human Rights. The letter was unrequited. Then, on April 30, 2015, Willie Sebastian complained again about the attitude of the Governor of Yogyakarta to *KOMNAS HAM*, and his complaint was replied to by the issuance of letter No. 069/R/Mediation/VIII/2015 concerning the Implementation of *KOMNAS HAM* Recommendations Related to Discrimination of Land Rights of Citizens of Chinese Descent in Yogyakarta Province (Chandran 2018). The content of the letter is that *KOMNAS*

HAM states that "... *submission of recommendations for a case of human rights violations to the government for follow-up resolution*. *The disregard of the Yigyakarta Governor's Brother on the recommendation of KOMNAS HAM No. 037/R/Mediation/VIII/2014 (August 11, 2014) can be indicated as a form of human rights violation in the form of systematic discrimination, as regulated by Article 104 paragraph (1) of Law No. 39 of 1999 concerning Human Rights".* The second recommendation of the *KOMNAS HAM* also had the same fate as the first recommendation. Willie Sebastian then wrote a letter to the president in 2015 accusing Yogyakarta's Sultan (who is also its governor) of discrimination (Varagur 2018). But it, too, had no effect.

During 2014 - 2018, Handoko, a lawyer of Chinese descent, sued the 1975 Instruction within the material test. In February 2015, he filed a lawsuit against Yogyakarta's Governor to the Supreme Court (Marwan 2018). His suit is known to have not been accepted since April 2015, but a copy of Supreme Court judgment No. 13 P/HUM/2015 was only received by Handoko in April 2016 after filing an application letter. The content of the judgment is: The application for objection to the applicant's Material Test Rights cannot be accepted because the Instruction of the Regional Head of DIY No. K 898/I/A/1975 does not include the laws and regulations as referred to in Article 7 paragraph (1) of Law No. 12 of 2011 concerning the Establishment of Laws and Regulations *juncto* Article 1 paragraph (1) of MA Regulation No. 1 of 2011 concerning The Right to Material Test, and Article 31 paragraph (1) of Law No. 5 of 2004 concerning the first amendment to Law No. 14 of 1985 concerning the Supreme Court and the second amendment to Law No. 3 of 2009 and Article 1 paragraph (1) of Supreme Court Regulation No. 1 of 2011 concerning the Right to Material Test.

Supreme Court Decision No. 13 P/HUM/2015 contains arguments from the legal team of the Yogyakarta's Provincial Government. In the Supreme Court Decision Document No. 13P/HUM/2015, they argued that the 1975 Instruction was in accordance with the customary law of the Sultanate. According to them, Indonesian Basic Agrarian Law is based on customary law and the principle of customary law is that only citizens can have full rights to land, namely in the form of property rights. At the same time, non-indigenous can only be given the right to use it. Furthermore, according to Law No. 13 of 2012 concerning Yogyakarta's specialness, the authority on land is attached to the Head of the Yogyakarta Region. The tribunal chaired by Hendro Cokro Mukti thwarted Handoko's suit in an audience on February 20, 2018 (Varagur 2018). Furthermore, in April 2018, Handoko appealed the Yogyakarta district court's decision that the ban was in accordance with the general principles of good governance. After nearly two months have passed, and there have been no bright spots from the appeal memorandum. Prior to this lawsuit, Handoko had already fought legally over this discriminatory policy, namely through a Judicial Review to the Supreme Court in 2015 and sued Yogyakarta's State Administrative Court in 2016.

The issue of discrimination of land title was reported to the OMBUDSMAN of the Republic of Indonesia by four people in March-May 2016. First, whistleblower Ida Cholidah from Yura Law Office as the attorney of Eni Kusumawati, with the reported head of the Bantul Land Office. Second, whistleblower Zealous Siput Lokasari, who reported the head of the Kulonprogo Land Office. Meanwhile, the third whistleblower Kus Sri Antoro is the power of attorney of Tan Susanto Tanuwijaya, with the reported head of the Jogja City Land Office. Next, the fourth whistleblower, Willie Sebastian reported all heads of the land office in Yogyakarta. Then, Zealous Siput Lokasari, in September 2016, took the initiative to submit a letter of condolence for Hamengkubuwono X to the Yogyakarta Governor's office but was unable to meet in person. Latest effort, Felix Juanardo Winata, a student of Gadjah Mada University, filed a lawsuit with the Constitutional Court regarding Article 7 paragraph (2) letter d of Law Number 13/2012 on November 14, 2019, which was considered to be a shield for discrimination in protecting the 1975 Instruction.

The resistances portrayed above denote those individual patterns have not received a response that is in line with expectations. Hence, group resistance began to emerge. It was recorded that there were two groups that carried out resistance, namely *Granad* and *Forpeta.*

3.3 GRANAD (Gerakan Anak Negeri Anti Diskriminasi/Nation's Child Against Discrimination Movement)

As a community movement, *GRANAD,* on February 7, 2015, attempted to carry out resistance by holding an audience with the Regional House of Representatives Council's regarding violations of the constitution in land policy in Yogyakarta (Humas 2015). In this regard, the leader of the *GRANAD* group, represented by Willie Sebastian, said that after the Specialness Law was enacted, it caused unrest for some residents, especially related to land in Yogyakarta. For this reason, *GRANAD* reports violations of the constitution in the land policy to: 1) The Minister of Agrarian Affairs and Spatial Planning/Head of the National Land Agency of the Republic of Indonesia, 2) The Corruption Eradication Commission, 3) The Head of the Police of the Republic of Indonesia, and 4) The Minister of Home Affairs of the Republic of Indonesia were sent by post and fax.

The Yogyakarta Regional People's Representative Council appreciated what *GRANAD* had conveyed, then said that what was certain was that the Yogyakarta Regional People's Representative Council could not position itself as a court so that everything went according to their respective portions. The Regional People's Representative Council also asked for written documents because they had to read up on several aspects, i.e., the juridical, sociological, and historical aspects. In this case, of course, everyone has an argument about placing this history into a single unit.

Regarding the juridical constitution, in the formation of laws and regulations, there is a hierarchical order of laws and regulations. Presidential Decree No. 33/1984 will look at the minutes of how this Presidential Decree was issued. The legal

position is debatable. However, this Presidential Decree is unable to annul the laws above. The Presidential Decree is not included in the legislative hierarchy; this is not equal to be compared with the legislative hierarchy. The Privilege Law in Article 7, paragraph 2 letter (d) clearly commands that one of them is land, customary interests, and local wisdom. In this Privileges Law, the existence of *lex specialis*, things like this should not be contradicted by the Basic Agrarian Law.

3.4 Forpeta (Forum Pembela Tanah/Land Care Forum)

Forpeta, on November 23, 2016, once tried to hold an audience with the special committee team on the draft of Special Regional Law on the 3rd floor of the Yogyakarta Regional People's Representative Council building (Humas 2016). During the audience, the *Forpeta* consisting of about 40 people, was met directly by the Head of the Special Committee Team and accompanied by members of the special committee. *Forpeta*, represented by Zealous Siput Lokasari, provided input to the special committee regarding the draft of a special regional regulation on the management and utilization of Sultanate Land and Duchy Land in Yogyakarta. The Yogyakarta Regional People's Representative Council, which was represented by the chairman of the special committee, said that suggestion from *Forpeta* would be accommodated and would be studied further so that it could later be taken into consideration for the next meeting. In addition, *Forpeta* has also sent a subpoena to the Governor of Yogyakarta accompanied by a document with a copy addressed to the President of the Republic of Indonesia and several state institutions and the public as a report related to land.

Eventually, after the death of Pakualam VIII as a signatory of the 1975 Instruction and the impact of the Reform Movement in 1998, ethnic Chinese were even noted to have begun opposing discriminative policy targeting them. The circumstances of the Chinese community in various discriminations gave rise to a solidarity movement to fight for their rights as citizens (Pelu and Purwanta 2020). The resistance carried out by the ethnic Chinese in Yogyakarta took official legal steps instead of physical resistance.

4. Conclusions

Ethnic Chinese in Yogyakarta has been experienced racial discrimination in land ownership rights for more than 25 years. The 1975 Instruction became the main and fundamental policy prohibiting the Chinese from holding ownership rights to land. Meanwhile, they have been discriminated against since 1975, and ethnic Chinese only began to resist it in 1998. Prior to 1998, ethnic Chinese in Yogyakarta chose to remain silent and obey in response to the discrimination because of the authoritarian political and culture in Indonesia generally, and Yogyakarta especially. Ethnic Chinese experienced poor acceptance due to the stigma that formed and evolved in Indonesian society, but they were still accepted to live a life in Yogyakarta. After 1998, the social conditions of the society at the national level of Indonesia and Yogyakarta began to undergo a slight change based on politics and culture due to the erodes of feudalism and authoritarianism. The regime change in 1998 became the determinant factor that made ethnic Chinese in Yogyakarta begin to resist. The resistance carried out by ethnic Chinese in Yogyakarta after 1998 continued to escalate into two. Individual resistance is carried out through legal actions. On the other hand, group resistance is carried out through the formation of communities to express aspirations freely in public. Although they look different, the two forms of resistance carried out by the ethnic Chinese in Yogyakarta are defined in public transcripts or better known as open resistance.

In conclusion, the Indonesian government needs to take serious steps to address the issue of racial discrimination in the land rights sector before it escalates into conflict. Considering that Indonesia as a plural and multicultural nation is a representation of the rejection of a homogeneous world as a negative impact of globalization.

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

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References

Carey P (1984) Changing Javanese Perceptions of the Chinese Communities in Central Java, 1755-1825. Indonesia 37:1–47.

Chandran R (2018) Indonesian lawyer fights decades-old ban on ethnic Chinese owning land. Thomson Reuters Foundation. Available in: https://jp.reuters.com/article/us-indonesia-landrights-lawyer-idUSKCN1GI0UM Accessed on: April 10, 2022.

Debebe Y, Taa B, Mengestie S (2022). The Genesis of Ethno-nations in Ethiopia: A Critical Appraisal. Ethiopian Renaissance Journal of Social Sciences and Humanities 9: 136–152. DOI: 10.20372/erjssh.2022.0901.07

Gottschalk L (1981) Understanding History: A Primary of Historical Method. Universitas Indonesia Press, Jakarta.

Hoon CY (2006) Assimilation, multiculturalism, hybridity: The dilemmas of the ethnic chinese in post-suharto Indonesia. Asian Ethnicity 7:149–166. DOI: 10.1080/14631360600734400

Humas (2015) Gerakan Anak Negeri Anti Diskriminasi (GRANAD) beraudiensi dengan DPRD DIY. DPRD Daerah Istimewa Yogyakarta. Available in: https://www.dprd-diy.go.id/gerakana-anak-negeri-anti-diskriminasi-granad-beraudiensi-dengan-dprd-diy Accessed on: July 24, 2022.

Humas (2016) Forpeta NKRI Kritisi Raperdais Pertanahan. DPRD Daerah Istimewa Yogyakarta. Available in: https://www.dprd-diy.go.id/forpeta-nkri-kritisi-raperdais-pertanahan Accessed on: July 24, 2022.

Kartodirjo S (1992) Pendekatan Ilmu Sosial dalam Metodologi Sejarah. Gramedia Pustaka Utama, Jakarta.

Kurniadi BD (2020) Defending the Sultan's Land: Yogyakarta, Aristocratic Power and Control over Land in Post-Autocratic Indonesia. Dissertation, The Australian National University.

Marwan A (2018) How Yogyakarta preserves discrimination. The Jakarta Post. Available in: https://www.thejakartapost.com/academia/2018/05/11/how-yogyakarta-preserves-discrimination.html Accessed on: April 10, 2022

Mustajab I (2022) From Affirmative into Discriminative: The Miserable Condition of the Indians and Chinese Land Rights in Special Region of Indonesia. Shidnij Svit 4: 282-287. DOI: 10.15407/orientw2022.04.282

Na'im A, Syaputra H (2010) Nationality, Ethnicity, Religion, and Languages of Indonesians (in Indonesian). Badan Pusat Statistik, Jakarta.

Najib A (2018) Perpanjangan Sertifikat HGB di Atas Tanah Negara Dipersulit, Warga Protes ke BPN. iNews Yogya. Available in: https://yogya.inews.id/berita/perpanjangan-sertifikat-hgb-di-atas-tanah-negara-dipersulit-warga-protes-ke-bpn Accessed on: April 15, 2022.

Park JB (2012) MANAGING SOCIO-ECONOMIC CRISIS IN INDONESIA: The role of interfaith civic organisations in Yogyakarta during the 1998 economic crisis. Indonesia and the Malay World 40:39-58. DOI: 10.1080/13639811.2011.648997

Pelu M, Purwanta H (2020) Pasang-Surut Relasi Tionghoa-Jawa Di Surakarta: Studi Kasus Etnis Tionghoa Di Kampung Balong. Patanjala Jurnal Penelitian Sejarah Dan Budaya 12. DOI: 10.30959/patanjala.v12i1.539

Purwanta H (2022) The History of Farmer Resistance toward the New Yogyakarta International Airport Construction in Kulon Progo Regency: A Social Movement Study. International Journal of Multicultural and Multireligious Understanding 9:29-42. DOI: 10.18415/ijmmu.v9i6.3773

Scott JC (1985) Weapons of the weak: Everyday forms of peasant resistance. Yale University Press, New Heaven.

Scott JC (1990) Domination and the arts of resistance: Hidden transcripts. Yale University Press, New Heaven.

Suryadinata L (1997) Ethnic Chinese as Southeast Asians. Institute of Southeast Asian Studies, Singapore.

Sutiyah S (2017) KEHIDUPAN POLITIK DI KOTA SURAKARTA DAN YOGYAKARTA MENJELANG PEMILIHAN UMUM 1955. Paramita: Historical Studies Journal 27: 195-211.

Tanasaldy T, Palmer C (2019) Discrimination, sport and nation building among Indonesian Chinese in the 1950s. Indonesia and the Malay World 47:47-65. DOI: 10.1080/13639811.2019.1559564

Tania RA, Satriawan I (2021) Discriminatory policy of land ownership of the Chinese in the special region of Yogyakarta in constitutional and local regulation perspective. E3S Web of Conferences 316.

Turner S, Allen P (2007) Chinese Indonesians in a rapidly changing nation: Pressures of ethnicity and identity. Asia Pacific Viewpoint 48:112-127. DOI: 10.1111/j.1467-8373.2007.00334.x

Varagur K (2018) Yogyakarta Region Upholds Decision to Bar Chinese Indonesians from Owning Land. VOA News. Available in: https://www.voanews.com/a/yogyakarta-upholds-decision-to-bar-chinese-indonesians-from-owning-land/4272423.html Accessed on: April 10, 2022.

Yuniar RW (2018) Why are ethnic Chinese still being denied land in Indonesia?. South China Morning Post. Available in: https://www.scmp.com/week-asia/politics/article/2136588/why-are-ethnic-chinese-still-being-denied-land-indonesia Accessed on: April 10, 2022.

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Acceptability of Sweet Potato (*Ipomoea batatas*) flour and Toasted Rice (*Orayza sativa*) Powder as Base Ingredients in Making Polvoron

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Abstract Sweet potatoes and rice are common food staples among Filipinos. Deterioration of these food commodities significantly affect their marketability which leads to create innovations for consumption and profitability. This study aimed to develop a polvoron made from sweet potato flour and toasted rice powder as base ingredients. This descriptive study utilizes mean to determine the level of acceptability of the respondents to the product. Each sensory quality of the sweet potato and toasted rice polvoron was rated on a Likert scale of 1 to 5. There were 150 respondents who were conveniently selected which composed of 25 households and 25 vendors from Sta. Cruz, Davao del Sur, 25 households and 25 vendors from Sulop, Davao del Sur, and 25 students and 25 faculty/staff from UM Digos College. The respondents' assessment in terms of palatability obtained a mean score of 4.63 (SD = 0.688), considered the most acceptable. Texture obtained a mean score of 3.87 (SD = 0.665), which was described as more acceptable. Aroma obtained a mean score of 4.72 (SD = 0.490), considered the most acceptable. Color obtained a mean score of 4.68 (SD = 0.489), considered the most acceptable, and appearance obtained a mean score of 4.80 (SD = 0.451), considered the most acceptable. The overall average rating of the product obtained a mean score of 4.54 (SD = 0.40). Moreover, the product described to be highly acceptable in terms of palatability, texture, aroma, color, and appearance. The data revealed that sweet potato and toasted rice powder can be base ingredients of polvoron. Thus, it is recommended that the texture shall be more refined. The product can be a good input for starting up a small business.

Keywords: palatability, texture, aroma, color, appearance, Philippines

1. Introduction

Food innovation is a significant way to reinvent or discover healthier and marketable delicacies. Polvoron is identified as one of the easiest and simplest pastry foods that can be produced instantly by local entrepreneurs and become a source of income, especially for unemployed citizens and Filipino households. It will also help improve farmers' interest by engaging in the extensive production of native crops (Gunnawa 2021). Polvoron contains high cholesterol and glucose content because of its tremendous amount of sugar (Soriano 2020). There are different versions of polvoron, but the Filipino version uses a large amount of flour, powdered milk, hydrogenated fats, and shortenings such as margarine or butter as a substitute for lard (Quimbo 2019). Sweet potato and rice are abundant in Davao del Sur and the Philippines. Blended pure powdered polvoron made of sweet potatoes and toasted rice powder has yet to be produced. Therefore, the researchers will produce an innovative mixture of polvoron using these great locally available products. Hence, the researchers conducted the study and focused on developing these available food crops in the locality and processing sweet potato and rice into powder to produce healthy and locally available polvoron.

Many countries, including the Philippines, are blessed with indigenous food crops which can be processed and sold to financially help families by selling the by-products to some business industries (Padilla et al 2016). Filipinos enjoy travel and are fond of eating unique delicacies. They even buy some as gifts or "Pasalubong" for their friends and families. Most delicacies are sweet but lack nutrients, resulting in health problems for some Filipinos who are very conscious about their health (Doblon-Merilles 2019). Improving the processing of delicacy into a salable commodity as a new choice of food product is prompted by the popularity of food crops. One of these crops is sweet potato (Llamera 2018).

Sweet potato is used substantially in Asia and South East Asian countries, the fact that processed products are usual in countries like Vietnam, Indonesia, Thailand, Malaysia, and the Philippines (Padmaja 2012). The leaves and roots of the sweet potato contain a variety of nutrients, including bioactive carbohydrates, proteins, carotenoids, flavonoids, anthocyanins, phenolic acids, and minerals, antioxidant, cardioprotective, anti-inflammatory, anti-cancer, anti-diabetic, antibacterial, anti-

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obesity and prevention of vitamin A deficiency are only a few of the health advantages (Alam 2021). Sweet potato is one of the most preeminent economic crops in many countries in yearly production. It is the fifth most important food crop in the tropics and the seventh in the world's food production, next to wheat, potato, barley, cassava, rice, and maize (FAO 2016). Sweet potato placed a significant role in food production globally, all of which have underlying implications for succeeding in the food requirements, lessening poverty, and increasing food security (El-Sheikha and Ray 2017).

In Asia, rice production benefited from the Green Revolution and has become one of the world's essential food production systems (Chivenge 2019). Rice is a primary food crop worldwide, and a significant amount of rice bran is produced as a by-product of rice milling (Wang 2021). Rice is rich in vitamins, especially thiamine, riboflavin, niacin, and dietary fibers, but unfortunately, rice does not supply the essential minerals sufficiently. Indeed, it is the most significant cereal providing 21% of global human per capita energy and 15% of per capita protein (Breeding and RI 2020).

The researchers conducted the study to utilize the available food crops in the locality and process sweet potato and toasted rice into powder to produce polvoron. Since there is a need for more studies regarding the product, the study focused on developing these crops as raw materials for making polvoron. The developed product might be a good input for a start-up business or a suitable proposal as a livelihood program of a specific banner project of any industry that continuously helps partner communities through extension activities. Generally, this study aimed to develop a polvoron made from sweet potato and toasted rice powder as based ingredients. Afterward, this research determined the acceptability level of the product as perceived by the respondents.

2. Materials and Methods

Respondents. One hundred fifty (150) respondents were conveniently selected, composed of household keepers, vendors, students, and teachers who participated in the sensory evaluation. Respondents were randomly selected using the following criteria: respondents must be 18 years old and above, household keepers and vendors must be bonafide residents of Santa Cruz and Sulop, Davao del Sur, and students and teachers must be from UM Digos College.

Instruments and Materials. A survey questionnaire was used to obtain the information required for this study. The study focuses on the palatability, texture, aroma, color, and appearance of sweet potato and toasted rice polvoron. Each sensory quality of the sweet potato and rice coffee polvoron was rated on a Likert scale of 1 to 5. The researchers have secured approval and confirmation from Sherwin Jumao-as, the author of the study entitled "Level of Acceptability of Chili Garlic Sauce Enhanced With Lemongrass", to adapt and utilize the survey form used in his study. Listed are the scoring guidelines, which are classified into five scales (see Supplementary Material).

The abundance of sweet potato and rice made the researchers to process powder and derived to a formulation of a typical polvoron recipe instead of using wheat flour as a base ingredient.

Table 1 Ingredients of sweet potato and toasted rice polvoron.

Unit	Description
144g	Sweet potato powder
224g	Rice coffee powder
185g	Skimmed milk
300g	Butter/Margarine
195g	Sugar
30ml	Vegetable oil

2.1. Design and Procedure

An experimental and descriptive research design was utilized to describe the acceptability level of the respondents toward the product produced.

Drying and powdering process. The sweet potato flour and toasted rice powder underwent a series of procedures as specified in figures 1 and 2.

2.2. Ethical Declaration

The researchers observed full ethical standards in the conduct of the study following the study protocol assessments and standardized criteria by the institution. The following steps were taken to gather the responses needed in the study, the researchers coordinated and secure approval and authorization from the UM Digos College Vice-President for Branch Operations, the College Dean, and the Barangay Captains of Barangay Zone 3, Santa Cruz and Barangay Poblacion, Sulop, Davao del Sur to conduct the study. Following the approval from the authorities, the researchers conducted the study with the respondents following ethical considerations such as voluntary participation, informed consent process, permission from the organization, and without biohazard and conflict of interest issues in collecting the data for the study and archiving with confidentiality. A validated questionnaire was utilized in evaluating the acceptability of sweet potato and toasted rice polvoron.

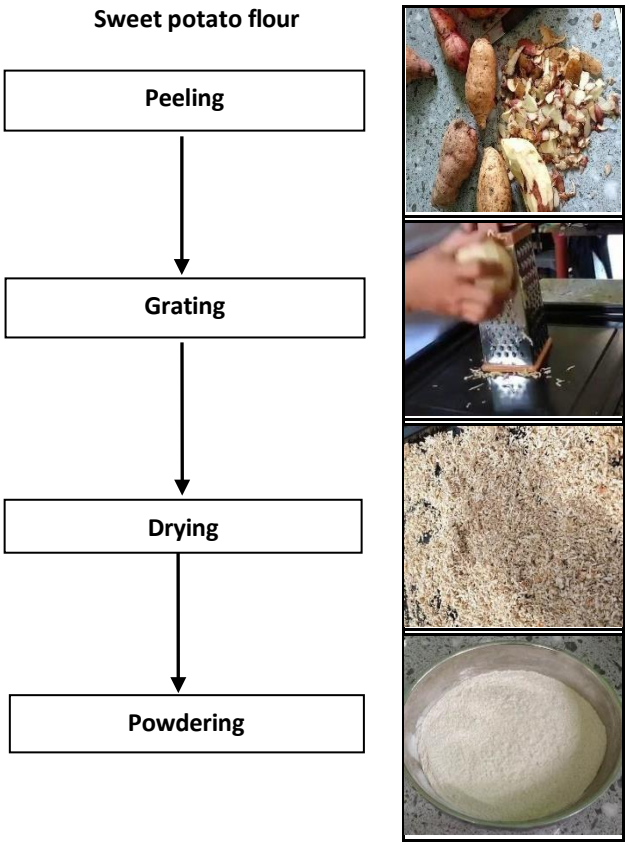

Figure 1 Drying and powdering process of sweet potato flour.

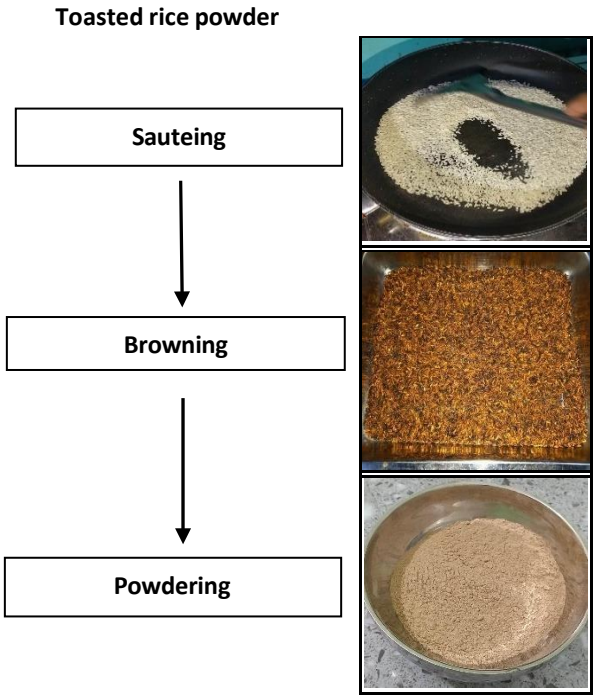

Figure 2 Drying and powdering process of toasted rice powder.

Methods of cooking sweet potato and toasted rice polvoron. The following procedures were observed by the researchers in preparing sweet potato and toasted rice polvoron (Figures 3 and 4):

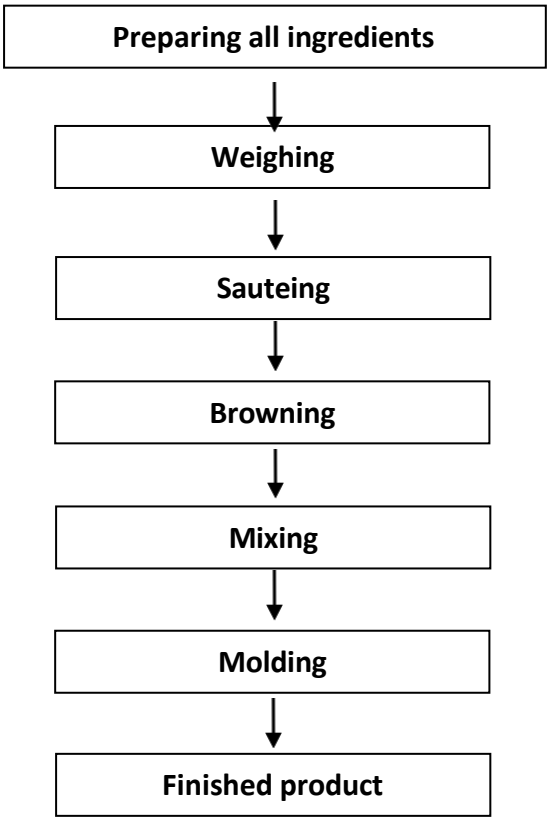

Figure 3 Drying and powdering process of toasted rice powder.

Figure 4 Finished product.

3. Results and Discussion

3.1 Characteristics of the Respondents

This study determined the profile of households and vendors from Santa Cruz and Sulop, Davao del Sur, and students and faculty from UM Digos College with an equal number of participants. Presented in Table 2 was the distribution of the participants. The first column showed the profile, the second column indicated the frequency, and the third determined the percentage.

Location/Type. The distribution of the participants in terms of the location revealed an equal population between Santa Cruz, Sulop, and UM Digos College participants, with the same percentage of 16.7.

Age. A frequency of 49 with a percentage of 32.67 is under the ages of 18 to 27. A frequency of 29 with a percentage of 19.33 is under the ages of 28 to 37. A frequency of 25 with a percentage of 16.67 is under the ages of 38 to 47. A frequency of 41 with a percentage of 27.33 is under the age of 48 and above. A frequency of 6 with a percentage of 4.0 is under the unidentified ages. It implies that 18 to 27 years old had the more significant number among all participants.

Table 2 Characteristics of the Respondents (n=150).

Profile	f	%
Location/Type		
Sta. Cruz Household	25	16.7
Sta. Cruz Vendor	25	16.7
Sulop Household	25	16.7
Sulop Vendor	25	16.7
UMDC Faculty	25	16.7
UMDC Student	25	16.7
Age		
18 – 27	49	32.67
28 – 37	29	19.33
38 – 47	25	16.67
48 and above	41	27.33
Unidentified	6	4.0
Total	150	100.0

3.2 Level of Acceptability

Palatability. The product's average rating based on the respondents' assessment obtained a mean score of 4.63 (SD = 0.688), considered the most acceptable. It signifies that the product is flavorful, creamy, and sweet. The delicious, naturally sweet crop is mixed with the slightly bitter toasted rice, combined with other essential ingredients to make it even tastier, and has an excellent result of sweet potato and toasted rice polvoron. Palatability plays an important role in food production. It was related to the assertion of Schiffman and Graham (2020) that the choice of a dish may be affected by palatability, which is comparable to the level of satisfaction a person derives from consuming food. Unlike how it tastes, food's palatability varies depending on the individual (Lowe 2007).

Texture. The product's average rating based on the respondents' assessment obtained a mean score of 3.87 (SD = 0.665), which was considered more acceptable. It means that the texture is slightly sandy and soggy. Since the sweet potato flour and the toasted rice powder are manually processed, as expected, the texture of the product is slightly sandy compared to other powders that are processed using a machine which results in a very fine texture. According to the study by Chen and Rosenthal (2015) that the texture of the food plays a crucial role in influencing consumers' preference for a food product. According to Foegeding et al (2011), when food structure is processed into a bolus by a difficult series of oral maneuvers, such as ingestion, processing, and swallowing. The texture of the food can be perceived.

Aroma. The product's average rating based on the respondents' assessment obtained a mean score of 4.72 (SD = 0.490), considered the most acceptable. It implies that the smell of the product is very strong and aromatic. As for aroma, the respondents rated it as the most acceptable because the respondents like how the product smells. Since, toasted rice is one of the base ingredients of the product, the aroma is a more coffee-like smell. The results show that respondents like the aroma of the product. It was thoroughly explained by Splenger (2009) that aroma is an essential quality of food that affect food choice behavior. It is well known that aromas can be appetizers.

Color. The product's average rating based on the respondents' assessment obtained a mean score of 4.68 (SD = 0.489), considered the most acceptable. It implies that the color of the product is coffee brown. The results reveal that the sweet potato and toasted rice polvoron obtained the highest ratings from the respondents for color. Toasted sweet potato flour has light brown color compared to toasted rice powder which has a darker brown color. The color of the toasted rice powder is more dominant than the color of sweet potato flour which resulted in a coffee brown color. Vanderbilt (2015) stated that food color affects how consumers become conscious of the flavor of the food before it is even tasted.

Appearance. The product's average rating based on the respondents' assessment obtained a mean score of 4.80 (SD = 0.451), considered the most acceptable. It signifies that the product is very appealing. The packaging or the outward look of the product is yet presentable and it is one of the big factors that affect the interest of the respondents. The findings reveal that the respondents valued the outward form of sweet potato and toasted rice polvoron. In your observations, Berčík et al (2021) rigorously explained that the food presentation sets particular expectations for the balance of flavor, delicacy, and overall quality, which in turn influences not only the actual consumption but also a variety of other aspects of the consumer's behavior.

Based on the respondents' assessment, the product's overall average rating for palatability, texture, aroma, color, and appearance acquired a mean score of 4.54 (SD = 0.400), which described the product as being most acceptable to the respondents (Figure 3, Table 3). It shows no significant difference in the acceptability of sweet potato and toasted rice polvoron among respondents.

Figure 3 Finished product.

Table 3 Level of Acceptability (n=150).

Indicator	Mean	SD
Palatability	4.63	0.688
Texture	3.87	0.665
Aroma	4.72	0.490
Color	4.68	0.489
Appearance	4.80	0.451
Overall	4.54	0.400

3.3 Levels of Acceptability Across Ages

Based on the assessment of respondents aged 18 to 27, palatability obtained a mean score of 4.59, considered the most acceptable (Table 4). It signifies that sweet potato and toasted rice polvoron are flavorful, creamy, and sweet. Texture obtained a 3.92 of the mean score, which is considered more acceptable. It implies that the product's texture is slightly sandy and soggy. Aroma obtained a mean score of 4.90, considered the most acceptable. It implies that the smell of the product is very strong and aromatic. The color obtained a mean score of 4.65, considered as the most acceptable. It implies that the color of the product is coffee brown. The appearance obtained a mean score of 4.78, considered the most acceptable. It signifies that the product is very appealing. Based on the assessment of respondents aged 18 to 27 years old, the overall average rating of the product attained a mean score of 4.57, considered the most acceptable, which signifies that the respondents were content with the output of this study.

However, in assessing respondents aged 28 to 37, palatability obtained a mean score of 4.72, considered the most acceptable. It signifies that the taste is flavorful, creamy, and sweet. Texture obtained a mean score of 3.93, which is considered more acceptable. It signifies that the texture is slightly sandy and soggy. Aroma obtained a mean score of 4.66, considered the most acceptable. It signifies that the smell of the product is very strong and aromatic. The color obtained a mean score of 4.62, considered the most acceptable. It signifies that the color of the product is coffee brown. The appearance obtained a mean score of 4.83, considered the most acceptable. It signifies that the product is very appealing. Based on the assessment of respondents 28 to 37 years old, the overall average rating of the product obtained a mean score of 4.55, considered the most acceptable, which signifies that the respondents were content with the output of this study.

Moreover, in assessing respondents aged 38 to 47, palatability obtained a mean score of 4.68, considered the most acceptable. It signifies that the taste is flavorful, creamy, and sweet. Texture obtained a mean score of 3.84, which is considered more acceptable. It implies that the texture is slightly sandy and soggy. Aroma obtained a mean score of 4.72, which is the most acceptable. It implies that the smell of the product is very strong and aromatic. The color obtained a mean score of 4.76, which is the most acceptable. It implies that the color of the product is coffee brown. The appearance obtained a mean score of 4.76, considered the most acceptable. It signifies that the product is very appealing. Based on the assessment of respondents aged 38 to 47 years old, the overall average rating of the product attained a mean score of 4.55, which is described as the most acceptable, which signifies that the respondents were content with the output of this study.

Furthermore, in assessing respondents aged 48 years old and above, palatability obtained a mean score of 4.59, considered the most acceptable. It signifies that the taste is flavorful, creamy, and sweet. Texture obtained a mean score of 3.83, which is considered more acceptable. It signifies that the texture is slightly sandy and soggy. Aroma obtained a mean score of 4.56, which is the most acceptable. It implies that the smell of the product is very strong and aromatic. The color obtained a mean score of 4.73, which is the most acceptable. It implies that the color of the product is coffee brown. The appearance obtained a mean score of 4.83, considered the most acceptable. It signifies that the product is very appealing. Based on the assessment of respondents aged 48 years old and above, the overall average rating of the product attained a mean score of 4.51, which is described as the most acceptable, which signifies that the respondents were content with the output of this study.

On the other hand, in the assessment of respondents who have unidentified ages, palatability obtained a mean score of 4.67, which is considered the most acceptable. It signifies that the taste is flavorful, creamy, and sweet. Texture obtained a mean score of 3.67, which is more acceptable. It implies that the texture is slightly sandy and soggy. Aroma obtained a mean score of 4.67, which is the most acceptable. It implies that the smell of the product is very strong and aromatic. The color obtained a mean score of 4.50, which is the most acceptable. It implies that the color of the product is coffee brown. The appearance obtained a mean score of 4.83, considered the most acceptable. It signifies that the product is very appealing. Based on the assessment of respondents who have unidentified ages, the overall average rating of the product attained a mean score of 4.47, which is considered the most acceptable, which signifies that the respondents were content with the output of this study.

As a whole, respondents from different levels of group ages rated the product as most acceptable. Sweet potato and toasted rice polvoron are said to be most acceptable due to their flavorful, creamy, and sweet taste, and they have a strong and aromatic smell that people like about the product. Aside from its excellent taste and aroma, the product is nutritious because of its based ingredients that are natural and nutritious.

Table 4 Level of acceptability across ages (n=150).

Age groups	Mean					
	Palatability	**Texture**	**Aroma**	**Color**	**Appearance**	**Overall**
18 – 27	4.59	3.92	4.90	4.65	4.78	4.57
28 – 37	4.72	3.93	4.66	4.62	4.83	4.55
38 – 47	4.68	3.84	4.72	4.76	4.76	4.55
48 and above	4.59	3.83	4.56	4.73	4.83	4.51
Unidentified	4.67	3.67	4.67	4.50	4.83	4.47

4. Conclusions

The data revealed that sweet potato flour and toasted rice powder could serve as base ingredients in making polvoron. Moreover, the product was described to be highly acceptable in terms of palatability, texture, aroma, color, and appearance.

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Conflict of Interest

The authors have declared that no competing interests exist.

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References

Alam MK (2021) A comprehensive review of sweet potato (*Ipomoea batatas* [L.] Lam): Revisiting the associated health benefits. Trends in Food Science & Technology 115:512-529.

Berčík J, Paluchová J, Neomániová K (2021) Neurogastronomy as a tool for evaluating emotions and visual preferences of selected food served in different ways. Foods 10:354.

Breeding A, RI M (2020) Diversity of Traditional Rice Varieties and Their Medicinal Benefits for Human Benefits. Life Sciences Leaflets 124:20-25.

Chen J, Rosentha A (2015) Modifying Food Texture and Structure. Woodhead Publishing.

Chivenge P, Sharma S (2019) Precision agriculture in food production: Nutrient management. In International workshop on ICTs for precision agriculture 12.

Doblon-Merilles RP, Quimbo MS (2019) Sensory evaluation of malunggay (Moringa oleifera) polvoron with sesame seeds. Int J Sci Res Eng Dev 2:660-674.

El-Sheikha AF, Ray RC (2017) Potential impacts of bioprocessing of sweetpotato: Review. Crit Rev Food Sci & Nutr 57:455–471.

FAO (2016) Crop Production Data. Available at: http://www.fao.org/faostat/en/#data/QC. Accessed on: December 29, 2016.

Foegeding EA, Daubert CR, Drake MA, Essick G, Trulsson M, Francisco V, Figueirinha A, Neves BM, Garcíarodríguez C, Lopes MC, Cruz MT, Batista MT (2011) Cymbopogon citratus as source of new and safe anti-inflammatory drugs: bioguided assay using lipopolysaccharide-stimulated macrophages. Journal of Ethnopharmacology 133:818-827.

Kemp SE, Hort J, Hollywood T (2018) Descriptive Analysis in Sensory Evaluation. Wiley Blackwell

Lowe (2007) Sensory Analysis. Availiable at: http://www.esac.pt/noronha. Accessed on: May 15, 2021.

Llamera EM (2018) Enhancing processing capability of indigenous people in Albay [Philippines] using sweet potato plus food products. In International Conference on Nutrition-Sensitive Agriculture and Food Systems: Strategic Approaches to Nutrition-Sensitive Agriculture and Food Systems in Southeast Asia, Tagaytay City (Philippines), 7-10 Nov 2018. Interdisciplinary Studies Center for Food and Nutrition Security.

Padilla DD, Saddul OI, Laborde GMR (2016) Development of a Healthy, Nutritious, and Delicious Tiesa (*Pouteria campechiana*) Polvoron. Journal of International Scholars Conference-ALLIED HEALTH 1:31-37.

Padmaja G, Sheriff JT, Sajeev MS (2012) Food uses and nutritional benefits of sweet potato. Fruit, Vegetable and Cereal Science and Biotechnology 6:115-123.

Schiffman SS, Graham BG (2000) Taste and smell perception affect appetite and immunity in the elderly. European journal of clinical nutrition 54:S54-S63.

Splengler (2009) The influence of food odor exposure on satiation and food choice. Available at: https://sensing. Kanicaminota. Us /2013/01/How – color-affects- your perception-of-food/. Accessed on: March 6, 2023.

Soriano MK, Tapalla N, Seranillo C, Coral T, Bastida MA, Tolato A (2020) Viability of Taro Flour as Ingredients of Polvoron at Bestlink College of the Philippines, SY 2019–2020. Ascendens Asia Singapore–Bestlink College of the Philippines Journal of Multidisciplinary Research 2.

Vanderbilt (2015) How color affects your perception of food. Available at: http://sensing.Konicaminolta.Us/2013/02/how-color-affectsyour perception-of food.

Wang N, Cui X, Duan Y, Yang S, Wang P, Saleh S, Xiao Z (2021) Potential health benefits and food applications of rice bran protein: research advances and challenges. Food Reviews International 1-24.

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The prevalence and determinants of gastrointestinal parasites of pigs in Roma, Lesotho

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Abstract The small-scale pig keeping in Lesotho has emerged as one of the common ways of subsistence for the vast majority of Basotho. Infection by gastrointestinal parasites is a common and persistent health threat that limits the extent to which the pig industry can potentially perform. Knowledge about the risk factors influencing parasitic infection is essential in order to make relevant interventions aimed at mitigating the occurrence and spread of parasites. A cross-sectional study was undertaken on 90 healthy pigs to determine the prevalence of gastrointestinal parasites. The floatation technique was utilized for laboratory analysis, and parasite eggs were identified based on the morphology. SPSS version 20.00 was used for analysis, from which Binary logistic regression was utilized. The overall prevalence of gastrointestinal parasites was 69%, the predominant specie was nematodes with 63% and the least was recorded for coccidian with 28%. Sows (79.6%, 32.7%) were more highly parasitized than boars (43.9%, 22.0%) in terms of nematodes and coccidian, respectively. Higher parasitic prevalence was recorded in young (76.5%, 35.3%) pigs than in older (46.2%, 17.9%) pigs both for nematodes and coccidian, respectively. It is therefore concluded that sex and age are the major determinants of parasitic infection in pigs.

Keywords: nematodes, coccidia, age, sex

1. Introduction

In recent years farming in Lesotho has taken a notable shift from subsistence to commercial and this shift might partly be explained by the escalating rate of unemployment in the country. Pig production in Lesotho has taken the lead as one of the income-generating farming activities, and this coincides with Onunkwo et al (2011) in Nigeria, who articulated that pig farming is practiced mainly as a family business. Regarding other livestock species, pigs are naturally highly prolific. Kyriazakis and Whittemore (2006) indicated that low prolific breeds could produce an average of eight live piglets per litter, while high prolific breeds can produce 13 piglets or more per litter.

Weka et al (2020) indicated that pig production contributes to poverty alleviation in different ways, including an increase in the food supply, source of income and a means for capital accumulation, employment opportunities, and supply inputs and services for crop production. Similarly, Akanni et al (2017) stated that pig farming remains a reliable component of the rural economy which mitigates and curbs the frustration of a higher unemployment rate. Despite the unfolding importance of the pig industry in the country, they are constantly confronted with several constraints, which include but are not limited to parasitic infection, which ultimately affect their production efficiency.

According to Atawalna et al (2016), parasitic infection accounts for a significant economic thread for pig production. Tumusiime et al (2020) articulated that the parasites for swine can be found in different body parts, including the lungs (*Metastrongylus* spp.), kidney (*Stephanurus dentatus*), muscle (*Cysticercus cellulosae*, *Toxoplasma gondii*), and gastrointestinal tract. Protozoa such as coccidia (*Cystoisospora* spp. and *Eimeria* spp.) and *Entamoeba* spp., as well as helminths, represent the common gastrointestinal track parasites (Tumusiime et al 2020). Retarded growth rate is one of the eminent signs of parasitic infection, particularly in piglets (Nonga and Paulo 2015). Abonyi and Njoga (2020) stated that at the advanced stage of parasite infection, the worms usually out-compete their hosts for nutrition and consequently affect the body condition score of an animal. Similarly, Geresu et al (2015) attested that parasites can potentially irritate intestinal mucosa, which has a detrimental impact on the digestion and absorption of nutrients.

Murthy *et al* (2016) further confirmed that a slight infection by *Ascaris suum* can result in reduced daily body weight gain as a result of decreased food intake. According to Agustina et al (2017) the prevalence of gastrointestinal parasites is influenced by the system of management (intensive, semi-intensive, and extensive), farm hygiene, geographical location, and antiparasitic prophylactic treatment such as deworming. Currently, there are no studies to elucidate the magnitude of parasitic

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infection in swine in Lesotho, hence why the current study was undertaken to explore the major determinants of infection in swine.

2. Materials and Methods

2.1. Description of the study site

The study was conducted in Roma Valley, which is in the foothills of the Maseru district, Lesotho. According to Olaleye et al (2022), foothills have an estimated area of about 4588 km^2 that lies between 1,800 and 2,000m above sea level and forms 15% of the total land area. Roma is a settlement under the Manonyane Community Council, some 34 kilometers southeast of Maseru, the capital of Lesotho.

2.2. Study animals

The study animals were pigs of different ages and sex groups managed intensively. The breed that was used in this study was Duroc. All sampled pigs were in good health states and were housed in pens. They were all from the foothills of Maseru District, which are known to have a mean annual rainfall of 900–1000mm and mean annual temperature of −8 to 30ºC

2.3. Study design and sampling

A cross-sectional study was undertaken on 90 pigs of different age and sex groups. The age of the pigs was obtained from the farmers' records, and accordingly, pigs were classified as old (>6 months) and young (<6 months). With the help of the extension officer from the Ministry of Agriculture and Food Security, a list of households keeping pigs within the selected villages was established. Households to participate in the study were randomly selected from the list.

2.4. Collection and processing of samples

Prior to sample collection, farmers from selected villages were sensitized on the purpose of the study and how it will be undertaken and samples were only taken from farms whose owners have consented. Faecal samples were taken directly from the rectum using disposable cloves and were packed in sample bottles that were clearly labeled. The labeling included the sex of the pig, its age, and the village. The samples were packed in a cooler box containing ice packs and were transported to the National University of Lesotho laboratory for analysis. The samples were processed within 48 hours of collection and were processed using the flotation method. In order to prepare the flotation solution, 400g of sodium chloride was dissolved in 1 liter of distilled water. From each sample, 3g was mixed with 50ml of the flotation solution to make a slurry, and the mixture was blended (Hansen and Perry 1990). After blending, the mixture was then sieved into the beaker, and four drops of amyl alcohol were added to the sieved mixture to treat bubbles which can be mistakenly counted as parasite eggs. Using the disposable pipettes, a few milliliters were drawn from the sample and the two chambers of the McMaster slides were filled. Eggs were examined microscopically (10× and 40×). The parasitic eggs were identified based on morphology (Adeppa et al 2014).

2.5. Data analysis

The data were analyzed using SPSS software (version 20.00). The prevalence of gastrointestinal parasites was calculated as the ratio between the number of infected animals and the total number of animals sampled. Binary logistic regression was used to assess the relationship between predictor variables (age, sex) and the prevalence of different gastrointestinal parasites. The confidence level was tested at 95%.

3. Results and discussion

The results presented in Table 1 summarize the prevalence rate of gastrointestinal parasites in the study area, the obtained overall prevalence rate for gastrointestinal parasites was 69% and the predominant parasites were nematodes at 63% and the least was recorded for coccidian at 28%. The level of mixed infection recorded in the current study was found to be 22%.

Table 1 The overall prevalence rate of gastrointestinal parasites.

Description	Examined	Infected	Prevalence (%)
Faecal samples	90	62	69
Nematodes	90	57	63
Coccidian	90	25	28

The overall prevalence rate of the current study is far different from 79%, which was reported by Nwafor et al (2019) in central Free State Province, South Africa. In the same way, the recorded prevalence rate of the current study differs enormously from 97%, 82%, 91%, and 93% reported from investigations undertaken in China, Botswana, Ghana, and Burkina Faso,

respectively (Tamboura et al 2006: Nsoso et al 2000: Boes et al 2000: Permin et al 1999). The 69% recorded in the current study is, however, higher than 61.4%, reported in Uganda by Roesel et al (2017). The discrepancies reported in different studies might be due to different timing of the sampling, the geography of the site, and the age of the stud animals (Roesel et al 2017). Apart from that, the variation between different studies might partly be explained by the difference in the management practices per individual farm, as Pettersson et al (2021) articulated that effective parasitic control does not only rely on the use of antiparasitic drugs but also requires various management practices performed at farm level.

The results of the current study, which show an overall prevalence of 63% for nematodes, are in close proximity with the findings of Boes et al (2000) in China, who reported 58% of nematodes. The current results are however below 72%, which was reported by Tumusiime et al (2020) in Rwanda.

The prevalence of coccidian (28%) recorded in the current study is almost equal to 27.8%, which was obtained from the study of Karamon et al (2007) in Poland. This rate of prevalence is, however, lower than the 40.7% and 47.2% reported by Roesel et al (2017) and Weng et al (2005) in Uganda and China, respectively. According to Tumusiime et al (2020), the disparities between different studies can be explained by variations in production systems. The current results provide ample evidence that nematodes represent the major health threat in the study area and this call for the attention of pig producers to revive their de-worming programs in such a way that it targets the nematodes.

The results of the current study showed the level of mixed infection as 22% is far below the findings of Dey et al (2014) in Bangladesh and Kagira et al (2012) in Kenya, who reported 96.4% and 84.2%, respectively. The current findings are, however, in close proximity to those of Nganga et al (2008) in Kenya, who reported a 31.3% level of mixed infection. The level of mixed infection obtained in the current is study contradicts the findings in Ghana by Atawalna et al (2016), who reported 7%. According to Nonga and Paulo (2015), co-infections affect the production and performance of pigs considerably. Due to subclinical infections, farmers are most likely to be unaware of the infections; however, the damage caused by endoparasites cannot be underestimated (Agustina et al 2017).

Table 2 summarizes the results on the prevalence of gastrointestinal parasites in different villages. It was observed that pigs in village 5 were significantly more infected than the other four villages both in terms of nematodes and coccidian. For comparison purposes, village 1 was regarded as the reference point both for nematodes and coccidian. In terms of nematodes, the odds of getting infected moving from village 1 to villages 2, 3, and 4 decreased significantly ($P<0.05$) by 0.48, 0.61, and 0.48 times, respectively. On the other hand, the chances of getting nematode eggs moving from village 1 to village 5 increased significantly ($p<0.05$) by 8.81 times. The chances of getting coccidian eggs moving from village 1 to villages 2, 3, and 4 decreased significantly ($p<0.05$) by 0.15, 0.64, and 0.51 times, respectively.

Table 2 The prevalence rate of GIPs in different villages.

Village	Examined	Prevalence (%)	S.E	Exp(B)
		Nematodes		
1	17	64.7[a]	0.11	1
2	17	47.1[b]	0.12	0.48
3	19	52.6[c]	0.11	0.61
4	17	47.1[b]	0.12	0.48
5	20	100[d]	0.00	8.81
		Coccidian		
1	17	29.4[a]	0.11	1
2	17	5.9[b]	0.05	0.15
3	19	21.1[c]	0.09	0.64
4	17	17.6[c]	0.09	0.51
5	20	60.0[d]	0.11	3.60

Percentages within the same column with different superscripts [(ab)] differ significantly, S.E= Standard error.

The obtained results in Table 2 indicate that all the pigs in village 5 tested positive for nematodes. This 100% prevalence rate can be attributed to several reasons, including poor management systems. Previous conducted studies have confirmed that animals reared under a good management system tend to possess strong immunity and demonstrate resistance to infectious diseases (Atawalna et al 2015; Sow et al 2012; Ahmed et al 2008). Similarly, Madke et al (2010) suggested that animal housing must be well-ventilated to maintain required humidity and air circulation since the growth of the parasites population is accelerated in high humidity and low light. Moreover, Roepstorff et al (2011) articulated that the conditions and the environment in which an animal is kept can potentially influence the level of infestation.

The results on how sex affects the prevalence of gastrointestinal parasites are presented in Table 3. The findings revealed that females were significantly ($p<0.05$) more infected than males both in terms of nematodes and coccidian. The chances of having nematodes and coccidian infection significantly decrease by 0.2 and 0.58 times, respectively, moving from females to males.

Table 3 Prevalence rate of GIPs in different sex groups.

Sex	Examined	Prevalence (%)	S.E	Exp(B)
		Nematodes		
Male	41	43.9[a]	0.07	0.20
Female	49	79.6[b]	0.05	1
		Coccidian		
Male	41	22.0[a]	0.06	0.58
Female	49	32.7[b]	0.06	1

Percentages within the same column with different superscripts [(ab)] differ significantly, S.E= Standard error.

The results of the current study, which show a higher infestation rate in females, are in line with the findings of Maganga et al (2019) in Southeast Gabon, who reported that females were mostly infected. Similar trend of infection has also been reported in Burkina Faso by Tamboura et al (2006). In accordance with the current findings, previous studies have also confirmed higher infestation rates in females (Nwafor et al 2019: Swai et al 2010).

According to Sangioni et al (2017), higher parasitic infestation in females could be the result of changes in some parameters, such as physiological status or reproductive function (pregnancy, parturition, and lactation), which can potentially weaken activities of the immune system thereby exposing animals to parasitic infection. Maganga et al (2019) further explained that female animals, particularly during late pregnancy and lactation, are highly susceptible to parasitic infection due to hormonal alterations that lower the resistance to nematodes which results in higher infections.

The current results contradict the findings of Dadas et al (2016) and Sowemimo et al (2012), who reported higher parasitic burden in males (28.15 % and 18.0 %) than in females (22.96 % and 7.0 %), respectively. Moreover, the findings of the current work disagree with the results of Adhikari et al (2021) in South Central Nepal, who reported higher parasitic infection in males (97.5%) than in females (87%). According to Li et al (2020), variations in the prevalence rate obtained from different studies could be explained by factors including detection procedures utilized, sample size, farm management, climatic variations, and the immune status of an animal.

The results on how age influences parasitic infection are presented in Table 4. The results revealed that young (76.5%) pigs were significantly more infected than young (46.2%) pigs. The likelihood of pigs getting nematodes and coccidian infection decreased significantly by 3.79 and 2.49 times, respectively, moving from old to young pigs.

Table 4 Prevalence rate of GIPs in different age groups.

Age	Examined	Prevalence (%)	S.E	Exp(B)
		Nematodes		
Young	51	76.5[a]	0.06	3.79
Old	39	46.2[b]	0.08	1
		Coccidian		
Young	51	35.3[a]	0.06	2.49
Old	39	17.9[b]	0.06	1

Percentages within the same column with different superscripts [(ab)] differ significantly, S.E= Standard error.

The results of this study, which revealed a higher infection rate in young pigs than older pigs, are in consonance with previous investigations of Maganga et al (2019), who reiterated that gastrointestinal parasites were highly prevalent in young pigs. Similar findings have been reported by several researchers (Roesel et al 2017: Dey et al 2014: Kagira et al 2012: Nsoso et al 2000). According to Tamboura et al (2006), a lower infestation rate in adult pigs can be as a result of established immunity after the first infection. Similarly, Corwin (1997) confirmed that adult pigs had acquired a more effective immune memory over time hence why they are lowlily infected.

The current findings are, however, in disagreement with the results of Sarker et al (2016), who reported similar infection rates across different age groups.

4. Conclusions

Based on the findings of this study, it is concluded that infection by gastrointestinal parasites is a common health thread in the study area, and nematodes represent the major challenge. Moreover, sex and age have been confirmed as the major determinants of infection by gastrointestinal parasites. With this knowledge, it would be easy for small-scale pig keepers to establish effective and relevant deworming programs.

Ethical considerations

The Research and Ethics Committee in the Department of Animal Science at the National University of Lesotho approved this study based on international animal welfare standards for the use of animals in conducting research.

Conflict of Interest

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References

Abonyi FO, Njoga EO (2020) Prevalence and determinants of gastrointestinal parasite infection in intensively managed pigs in Nsukka agricultural zone, Southeast, Nigeria. Journal of Parasitic Diseases 44:31–39. DOI: 10.1007/s12639-019-01158-8

Adeppa J, Ananda KJ, Krishna Murthy CM, Satheesh GM (2014) Incidence of gastro intestinal parasites in horses of Shimoga region, Karnataka state. Journal of Parasitic Disease 40:919–921. DOI: 10.1007/s12639-014-0605-5

Adhikari RB, Dhakal MA, Thapa S, Tirth RG (2021) Gastrointestinal parasites of indigenous pigs (*Sus domesticus*) in south-central Nepal. Veteterinary Medicine Science 7:1820–1830. DOI: 10.1002/vms3.536

Agustina KK, Swacita IBN, Oka IBM (2017) Reducing zoonotic and internal parasite burdens in pigs using a pig confinement system. Veterinary World 10:1347–1352. DOI: 10.14202/vetworld.2017.1347-1352

Ahmed MI, Tijjani AN, Mustapha AR (2008) Survey for common diseases and management practices of donkeys (*Equus asinus*) in Borno, State Nigeria. Nigerian Veterinary Journal 29:1–5. DOI: 10.4314/nvj.v29i3.3597

Akanni ON, Anyika KC, Migap CF, Jatau JD (2017) Prevalence of gastro-intestinal parasites in pigs in Jos South Local Government Area of Plateau State, Nigeria. Haya Saudi Journal of Life Science 2:140–142. DOI: 10.21276/haya

Atawalna J, Emikpe BO, Sallah EK, Shaibu W, Folitse RD (2015) The health problems, gastrointestinal and blood parasites commonly associated with donkeys in the upper east Region of Ghana. African Journal of Biomedical Research 18:37–41.

Atawalna J, Folitse RD, Amenakpor C (2016) Prevalence of gastrointestinal parasites among pigs in the Ejisu Municipality of Ghana, Scholars Journal of Agriculture and Veterinary Sciences 3:33–36.

Boes J, Willingham AL, Fuhui S (2000) Prevalence and distribution of pig helminths in the Dongting Lake Region (Hunan Province) of the People's Republic of China. Journal of Helminthology 74:45–52.

Corwin RM (1997) Pig parasite diagnosis. Swine Health and Production 5:67–70.

Dadas S, Mishra S, Jawalagatti V, Gupta S, Vinay TS, Gudewar J (2016) Prevalence of gastrointestinal parasites in pigs (Sus scrofa) of Mumbai region. International Journal of Science, Environment and Technology 5:822–826.

Dey TR, Dey AR, Begum N, Akther S, Barmon BC (2014) Prevalence of endoparasites of pig at Mymensingh, Bangladesh. IOSR Journal of Agriculture and Veterinary Science 7:31–38.

Geresu MA, Hailemariam Z, Mamo G, Tafa M, Megersa M (2015) Prevalence and associated risk factors of major gastrointestinal parasites of pig slaughtered at Addis Ababa Abattoirs Enterprise, Ethiopia. Journal of Veterinary Science & Technology 6.

Hansen J, Perry B (1990) The epidemiology, diagnosis and control of gastrointestinal parasites of ruminants in Africa. A hand book. Nairobi: International Laboratory for Research on Animal Diseases.

Kagira JM, Kanyari PN, Githigia SM, Maingi N, Nganga JC, Gachohi JM (2012) Risk factors associated with the occurrence of nematodes in free-range pigs in Busia District, Kenya. Tropical Animal Health Production 44:657–664. DOI: 10.1007/s11250-011-9951-9

Karamon J, Ziomko I, Cencek T (2007) Prevalence of Isospora suis and Eimeria spp. in suckling piglets and sows in Poland. Veterinary parasitology 147:171–175. DOI: 10.1016/j.vetpar.2007.03.029

Kyriazakis I, Whittemore CT (2006) Whittemore's science and practice of pig production. 3rd Edition. Blackwell Publishing.

Li YH, Yao Q, Dong HP, Wang SS, Chen RR, Song JK, Yan WC, Zhao GH (2020) Molecular characterization of Balantioides coli in pigs from Shaanxi province, northwestern China. Parasitology Research 119:3075–3081. DOI: https://doi.org/10.1007/s00436-020-06800-6

Madke PK, Lathwal SS, Singh Y, Kumar A, Kaushik V (2010) Study of behavioural and physiological changes of crossbred cows under different shelter management practices. Indian Journal of Animal Sciences 80:771–774.

Maganga GD, Kombila LB, Boundenga L, Moussadji Kinga IC, Obame-Nkoghe J, Tchoffo H, Gbati OB, Awah-Ndukum J (2019) Diversity and prevalence of gastrointestinal parasites in farmed pigs in Southeast Gabon, Central Africa, Veterinary World 12:1888–1896. DOI: 10.14202/vetworld.2019.1888-1896

Murthy CMK, Ananda KJ, Adeppa J, Satheesha MG (2016) Studies on gastrointestinal parasites of pigs in Shimoga region of Karnataka. Journal of Parasitic Diseases 40:885–889. DOI: 10.1007/s12639-014-0598-0

Nganga CJ, Karanja DN, Mutune MN (2008) The prevalence of gastro- intestinal helminth infections in pigs in Kenya. Tropical Animal Health and Production 40:331–334. DOI: 10.1007/s11250-007-9112-3

Nonga HE, Paulo N (2015) Prevalence and intensity of gastrointestinal parasites in slaughter pigs at Sanawari slaughter slab in Arusha. Tanzania, Livestock Research for Rural Development 27.

Nsoso SJ, Mosala KP, Ndebele RT, Ramabu SS (2000) The prevalence of internal and external parasites in pigs of different ages and sexes in Southeast District, Botswana. Onderstepoort Journal of Veterinary Research 67:217–220.

Nwafor I, Roberts H, Fourie P (2019) Prevalence of gastrointestinal helminths and parasites in smallholder pigs reared in the central Free State province. Onderstepoort Journal of Veterinary 86:1–8. DOI: 10.4102/ojvr.v86i1.1687

Olaleye A, Mating R, Nkheloane T, Tuku KS, Akande TY (2022) Wetland health in two agro-ecological zones of Lesotho soil Physic- Chemical Properties Nutrient Dynamics and Vegetation IsotopicN^{15}. Soils Science- Emerging Technologies, Global Perspective and Applications. DOI: 10.5772/intechopen.101836

Onunkwo JI, Njoga EO, Nwanta JA, Shoyinka SVO, Onyenwe IW, Eze JI (2011) Serological survey of porcine *Brucella* infection in Southeast, Nigeria. Nigeria

Veterinary Journal 32:60–62. DOI: 10.4314/nvj.v32i1.68989

Permin L. Yelifari P. Bloch N. Steenhard N. Hansen P, Nansen P (1999) Parasites in cross-bred pigs in the Upper East Region of Ghana. Veterinary Parasitology 87:63–71. DOI: 10.1016/s0304-4017(99)00159-4

Pettersson E, Halvarsson P, Sjolund M, Grandi G, Wallgren P, Hoglund J (2021) Firstreport on reduced efficacy of ivermectin on Oesophagostomum spp. on Swedish pigfarms. Veterinary Parasitology: Regional Studies and Reports 25:100598.

Roepstorff A, Mejer H, Nejsum P, Thamsborg SM (2011) Helminth parasites in pigs:New challenges in pig production and current research highlights. Veterinary Parasitology 180:72–81. DOI: 10.1016/j.vetpar.2011.05.029

Roesel K, Dohoo I, Baumann M, Dione M, Grace D, Clausen P (2017) Prevalence and risk factors for gastrointestinal parasites in small-scale pig enterprises in Central and Eastern Uganda. Parasitology Research 116:335–345. DOI: 10.1007/s00436-016-5296-7

Sangioni LA, de Avila Botton S, Ramos F, Cadore G.C, Monteiro S.G, Pereira D.I.B, Vogel F.S.F (2017) *Balantidium coli* in pigs of distinct animal husbandry categories and different hygienic-sanitary standards in the central region of Rio grande do sul state, Brazil. Acta Sciencetia Veterinariae 45:1–6. DOI: org/10.22456/1679-9216.80041

Sarker S, Begum N, Dey AR, Roy PP, Yadav SK, Mondal HMM (2016) Prevalence of endoparasites in pig in Chittagong, Bangladesh. International Journal of Natural and Social Sciences 3:52–58.

Sow A, Kalandi KM, Ndiaye NP, Bathily A, Sawadogo GJ (2012) Clinical biochemical parameters of Burkinabese local donkey breeds. International Research Journal of Biochemistry and Bioinformatics 2:84–89.

Sowemimo OA, Asaolu SO, Adegoke FO, Ayanniyi OO (2012) Epidemiological survey of gastrointestinal parasites of pigs in Ibadan, Southwest Nigeria. Journal of Public Health and Epideiology 4:294-298.

Swai ES, Kaaya EJ, Mshanga DA, Mbise WE (2010) Survey on gastrointestinal parasites of non-descript dogs in and around Arusha municipality, Tanzania. International Journal of Animal and Veterinary Advance 3:63–67.

Tamboura H, Banga-Mboko H, Maes D, Youssao I, Traore A, Bayala B, Dembele M (2006) Prevalence of common gastrointestinal nematode parasites in scavenging pigs of different ages and sexes in eastern center province, Burkina Faso. Onderstepoort Journal of Veterinary Research 73:53–60. DOI: 10.4102/ojvr.v73i1.169

Tumusiime M, Ntampaka P, Niragire F, Sindikubwabo T, Habineza F (2020) Prevalence of Swine Gastrointestinal Parasites in Nyagatare District, Rwanda. Journal of Parasitology Research 2020. DOI: https://doi.org/10.1155/2020/8814136

Weka R, Bwala D, Adedeji Y, Ifende I, Davou A, Ogo N, Luka P (2020) Tracing the Domestic Pigs in Africa. DOI: 10.5772/intechopen.95077

Weng YB, Hu YJ, Li Y (2005) Survey of intestinal parasites in pigs from intensive farms in Guangdong Province, People's Republic of China. Veterinary Parasitology,127:333–336. DOI: 10.1016/j.vetpar.2004.09.030

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Pose detection using deep learning for gait assessment

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Abstract This approach of gait analysis helps in solving the problems associated with the health of aged people by concentrating on the frailty and senility syndromes that affect elderly individuals. Deterioration of cognitive and motor abilities is a common result of ageing and has an effect on elderly people's quality of life. Some studies have connected these changes in gait patterns to the decline in cognitive and motor function. As a result, gait analysis is a useful tool for diagnosing senility and frailty diseases. By transferring the pose estimation data to a correct statistical analysis, gait analysis can be carried out utilizing machine learning and computer vision approach, allowing physiotherapists to analyse and treat patients accordingly. The main problem observed is that physiotherapists will analyse stroke patients' walking patterns on their own. As a result, this approach solves the problem by providing an accurate result of the observation. As everything is computerised, proper treatment can be provided with accurate data. A physiotherapist could also use machine learning classification techniques to analyse and classify the observed disorder and correct it. Our study mainly focuses on using machine learning approach instead of traditional sensor based or consultation just by vision. This will serve as a newer and better proposition of the same.

Keywords: computer vision, physiotherapy, keypoints, pose

1. Introduction

Human walking has typically been discussed in the context of medicine. The association between human walking and disease symptoms like frailty and dementia has been discussed in relation to a number of areas, including orthopaedics, rheumatology, neurology, and rehabilitation.

Gait analysis, which involves quantifying and interpreting measurable gait data, is one of the most popular methods used to learn more about the subject (Saboor 2020). This method, which is based on subjective measurements, is primarily carried out in a clinical setting by experts. Nowdays, many machine learning techniques are involved in the field of medicine. (RV Belfin 2020).

Our study uses computer vision to characterize the environment and people's behaviour in ambient assisted living (Mehdizadeh 2020). We specifically use computer vision to identify frailty and dementia symptoms in elderly individuals by observing how they move and assess the health of a person though there are various other sensor based methods. (Gujarathi 2019)

Using pose estimation, a computer vision approach, we get a pose data of the model. People are one type of flexible object pose. Key points will be in different positions in relation to others when our arms or legs are bent. Rigid posture estimate is the process of predicting where these items will be. Pose estimation gives us the ability to monitor an object or person in actual space quite precisely. A vast array of potential applications are made feasible by this potent feature. There are many gait assessment tools and softwares available out of which pose estimation differs from other common computer vision tasks in some significant ways (Jarchi 2018). Finding objects in an image is a task known as object detection. The object is typically contained within a bounding box in this localization, which is typically coarse-grained. Pose estimation goes one step further by detecting the exact location of the object's key elements. In terms of gait analysis, wearable sensors are mostly used in this process. Until now, physiotherapists have found this to be a useful input device. Sensors attached to the gait are primarily used to evaluate the patients and their gait (Zhang 2020). Predicting poses and estimating the walking pattern utilising key points can serve as an evolving perspective on gait analysis, even though machine learning has taken over the same subject. Squat count can also be used as a tool for evaluating a patient's fitness level for individuals with gait disorders like neuropathic gait, arthritis, and stroke. The image processing-based digital count can be improved upon in addition to the currently available capabilities.

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The goal of gait analysis (Saboor 2020) is to monitor and analyse data from a live video processing project using machine learning to visualize the walking patterns of elderly people or stroke patients and to obtain an observed statistical report or analysis on how the walking pattern is as a data to be provided to physiotherapists for further treatment and analysis.

2. Materials and Methods

Pose estimation can be done using the Deep Learning algorithm as follows:

2.1. Pose Estimation

A computer vision task called pose estimation infers the pose of a person or object in a picture or a video as the raw data (Makihara 2010). Pose estimation can alternatively be defined as the challenge of figuring out the location and orientation of a camera in relation to a specific person or item. We first get the pose skeletal of the live video and display the same (R. Dabral 2019). Pose estimation gives us the ability to monitor an object or person in actual space quite precisely (Figure 1).

Detecting, associating, and tracking semantic key points are all part of the computer vision task of human pose estimation and tracking. "Left knees," "right shoulders," and "vehicle's left brake lights" are a few examples of semantic key points . Pose estimate accuracy has been hampered by the large computer resources needed for semantic key point tracking in the real-time video (Akhtaruzzaman 2016). It is significant because it may be used in numerous applications, including activity identification and higher-level reasoning in the interaction between humans and computers.

Figure 1 Pose estimation.

2.2. Gait Analysis

The gait analysis is a thorough analysis with the primary purpose of examining how people move. As a result, gait analysis is successfully used to estimate poses. It can be done through simple observation or three-dimensional analysis with measured data of joint angles (kinematics), joint forces (kinetics), muscular activity, foot pressure, and energetics (measurement of energy expended during an activity), enables the doctor to create treatments that are specifically suited to each patient's needs.

This is frequently employed in clinical research to assist in understanding gait irregularities and their association with a particular underlying medical condition for better diagnosis and prognosis.This is done using machine leanring techniques involving different deep learning algorithms (Zeng 2020). For this, a variety of technologies that are integrated into specialised devices are being used, which include wearable devices, force platforms embedded in walkways, Inertial Measurement Unit (IMU) sensors, and computer-interfaced video cameras to measure patient motion (M Asif 2022). Electrodes placed on the skin's surface also help to understand muscle activity.

2.3 Pose Estimation in Gait Analysis

The approach to gait analysis using Machine Learning is discussed in this method. With the obtained pose estimation, we classify and analyse the pattern using algorithms specifically for the same implemented with high knowledge in the domain of physiotherapy, thereby providing solutions with the obtained statistical data. Using Human Pose Estimation, the joints in the human body can be first identified and then classified based on a predefined set of coordinates for each joint in the body (L.Lee 2002)(Figures 2 and 3). Using the CNN algorithm, the key points and patterns are recognized and fed as input to the gait analysis system (Figures 4 and 5).

These key points are defined by two metrics whether the joints are found or not - Percentage of Detected Joints (PDJ) and Object Key point Similarity (OKS), out of which Percentage of Detected Joints (PDJ) is computed by equation (1),

$$\text{PDJ} = \sum_{i=1}^{n} bool\,(\,\mathbb{d}_i < 0.05 * \mathbb{d}iagnol) \,/\, \text{n} \qquad (1)$$

Where the mentioned values represent the following:
di denotes the Euclidian distance between the ground truth key point and the predicted key point;
bool denotes the condition stating 1 if the condition is true and 0 if the condition is false;
n is the number of key points.

Our study uses computer vision to characterize the environment and people's behaviour in ambient assisted living. Widely, gait analysis is used for elderly people to detect syndromes and treat stroke patients (Ye 2015). However, our goal goes beyond the analysis of this particular set of people to encompass all ages and activities, including sports, rehabilitation, paediatric syndromes, and a wide range of other instances.

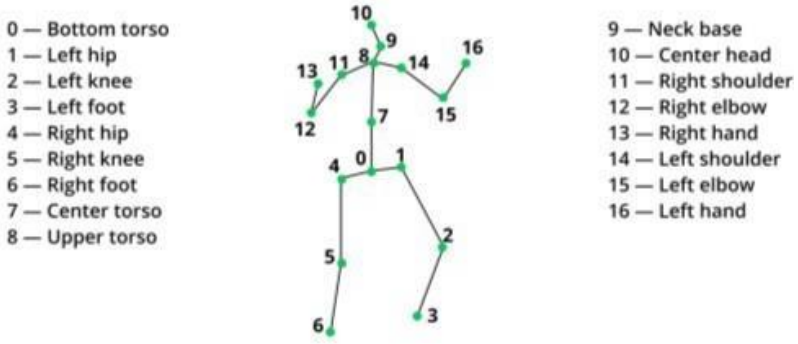

Figure 2 Key points and their specification.

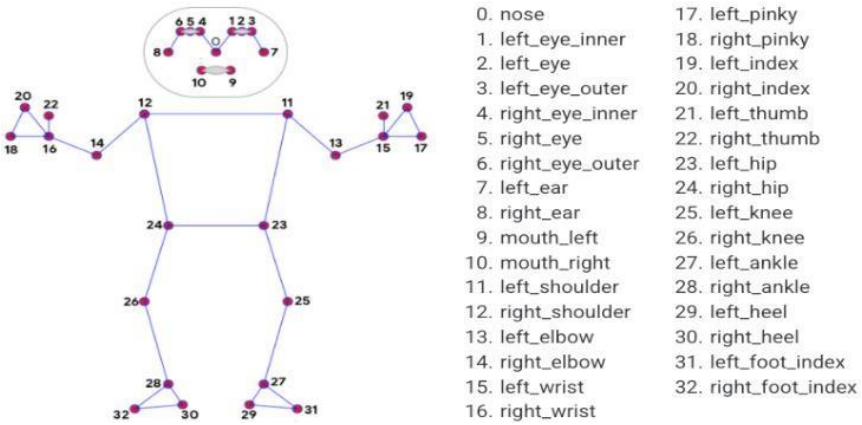

Figure 3 Joints and respective key points.

2.4. Working flow - Process

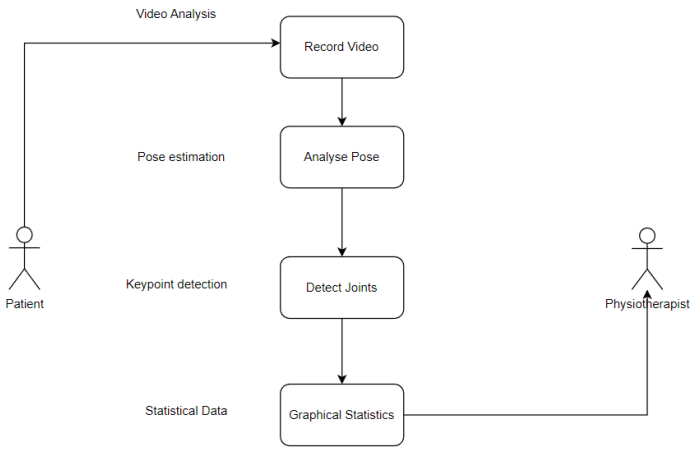

Figure 4 Process flow diagram.

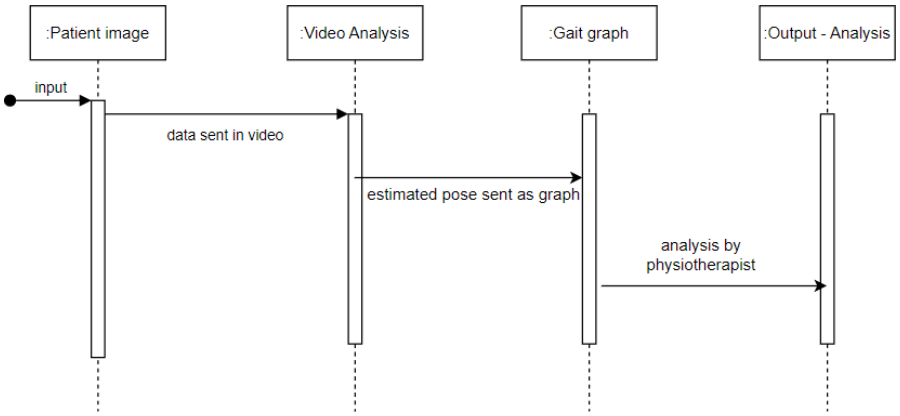

Figure 5 Sequence diagram.

3. Results and discussion

3.1 Observations based on the study

We have noted throughout our examination of the state of the art that the parameters of gait that have been studied are primarily related to the physiology of gait, which we find causally coherent because a phenomenon is characterized in terms of the parameters that control it. Pose estimation gives us the ability to monitor an object or person in actual space quite precisely. A vast array of potential applications is made feasible by this potent feature. Pose estimation also differs in some significant ways from other typical computer vision tasks. Object detection is a task that locates objects in an image. However, this localization is usually coarse-grained and consists of a bounding box that contains the object. Pose estimation takes a step further by foretelling the precise location of the object's key points. We haven't implemented gait assessment using the internet of things because usage of the same will cost a lot of sensors, and the integration part can be tedious. Considering the factors such as latency and environmental requirements for the proper working of the sensors and wearable sensors require monitoring. Therefore, this would be an easy way of analysing the gait. This perspective of gait analysis is very affordable because of the fact that it requires only a camera of good quality and a developed program to view the patient's skeletal image. Hence, this can be considered a very affordable system.

A gait graph can be generated by implementing the above, where the curves represent how a single gait variable varies over the gait cycle. The vertical lines across the full height of the graph represent foot-off and the tick marks represent opposite foot-off (to the left of the graph) and opposite foot contact (to the right. With the obtained graph, physiotherapists can analyse the abnormalities in gait. Eight fundamental pathological gaits, including hemiplegia, spastic diplegia, neuropathic, myopathic, Parkinsonian, choreiform, ataxic (cerebellar), and sensory, can be linked to neurological diseases.

Observing these gaits is a crucial part of diagnosis and can reveal details about a number of neurological and musculoskeletal problems. For calculating angles, we need coordinates of the **shoulder**, **hip**, **knee**, and **ankle**, which can be obtained from landmark points. Pose predicts the location of 33 pose landmarks.

3.2 Types of Models

It is studied and observed that there are basically three main human body models, out of which pose estimation uses the skeleton-based model to analyse the gait (Figures 6, 7.1, 7.2, 7.3, and 7.4).

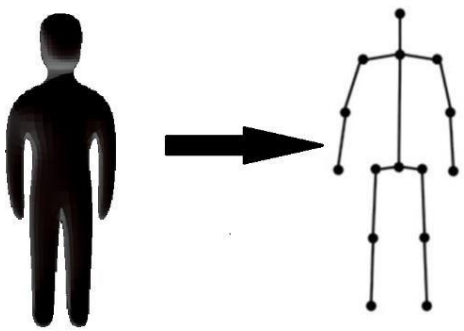

Figure 6 Types of human body models.

3.3 Test Cases

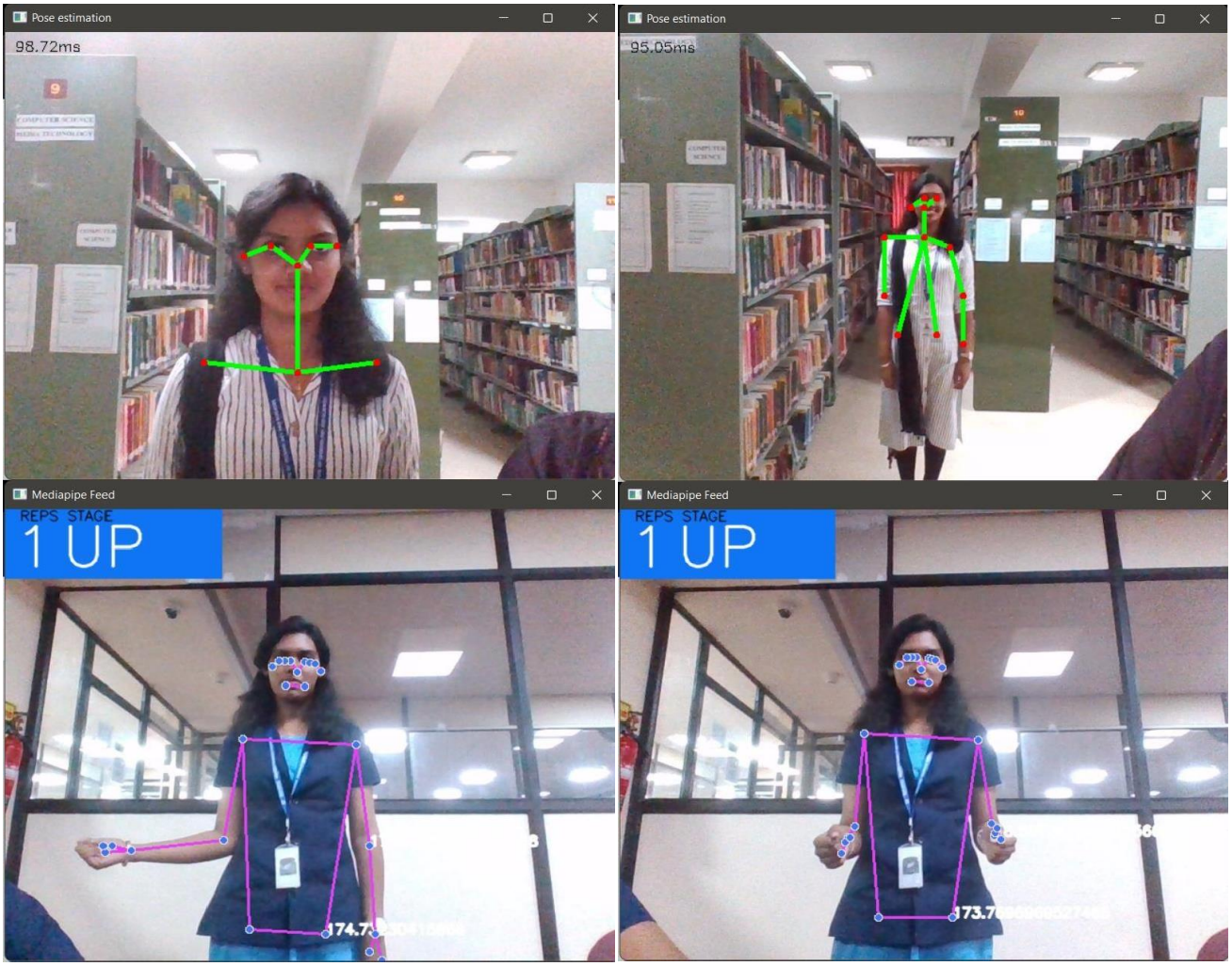

Figure 7.1 Face point detection. **7.2** Pose to detect points in the shoulders and hands. **7.3** Angle detections. **7.4** Curvatures and angles estimation.

4. Conclusions

The results for diagnosis have improved as the sensor-based approach has given way to sensor-less methods, and now the advancement of computer vision gives a better view of gait, along with different gait parameters being studied and taken into account. Though, clinical gait analysis is extremely important in the diagnosis, prevention, and monitoring of various ailments, whether they are neurological, cardiopathic, or orthopaedic in nature, this approach serves as helpful. Machine learning algorithms are used to estimate the graphical analysis of the poses. The outcome is obtained after analysing the obtained data. The fact that implementing machine learning specializing in the field of pose estimation can help in analysing the gait. The accuracy can be a matter of concern due to just the video feed as the input. In the case of implementation with sensors, the accuracy can be further improvised.

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Ethical considerations

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

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References

Akhtaruzzaman MD, Shafie AA, Khan R (2016) Gait Analysis: Systems, Technologies, And Importance. Journal of Mechanics in Medicine and Biology 16:1630003. DOI: 10.1142/S0219519416300039

Asif M. Analysis of Human Gait Cycle With Body Equilibrium Based on Leg Orientation. IEEE Access, 2022, DOI: 10.1109/ACCESS.2022.3222859

Belfin RV, Grace MKE, Suman (2020) Application of Machine Learning in the Social Network Recent Advances in Hybrid Metaheuristics for Data Clustering. DOI: 10.1002/9781119551621.ch4

Dabral R, Gundavarapu NB, Mitra R, Sharma A, Ramakrishnan G, Jain A (2019) Multi-Person 3D Human Pose Estimation from Monocular Images International Conference on 3D Vision (3DV), pp. 405-414. DOI: 10.1109/3DV.2019.00052

Gujarathi, Trupti, Bhole, Kalyani (2019) Gait Analysis Using Imu Sensor 1-5. DOI: 10.1109/ICCCNT45670.2019.8944545

Human Pose Estimation Using Machine Learning in Python**.** Available in: https://www.analyticsvidhya.com/blog/2021/10/human-pose-estimation-using-machine-learning-in-python/ Accessed on: April 7, 2023.

Jarchi D, Pope J, Lee TKM, Tamjidi L, Mirzaei A, Sanei S (2018) A Review on Accelerometry Based Gait Analysis and Emerging Clinical Applications. IEEE Reviews in Biomedical Engineering 11:177-194. DOI: 10.1109/RBME.2018.2807182

Lee L and W. E. L. Grimson, "Gait analysis for recognition and classification. Proceedings of Fifth IEEE International Conference on Automatic Face Gesture Recognition pp. 155-162. DOI: 10.1109/AFGR.2002.1004148.

Mehdizadeh S, Laboni A, Mansfield A, Flint A, Taati B (2020) Measuring Gait Variables Using Computer Vision to Assess Mobility and Fall Risk in Older Adults With Dementia. IEEE Journal of Translational Engineering in Health and Medicine 8:1-9. DOI: 10.1109/JTEHM.2020.2998326

Pose Estimation. Metrics. Available in: https://stasiuk.medium.com/pose-estimation-metrics-844c07ba0a78 Accessed on: April 7, 2023.

Ye, Minxiang, Yang, Cheng, Stankovic, Vladimir, Stankovic, Lina, Kerr, Andy (2015) Gait analysis using a single depth camera. DOI: 10.1109/GlobalSIP.2015.7418202

Zeng, Wei, Ismail, Shiek, Pappas, Evangelos (2020) Classification of gait patterns in patients with unilateral anterior cruciate ligament deficiency based on phase space reconstruction, Euclidean distance and neural networks. Soft Computing 24. DOI: 10.1007/s00500-019-04017-z

Zhang Y, Guo, Zanotto D (2020) Accurate Ambulatory Gait Analysis in Walking and Running Using Machine Learning Models IEEE. Transactions on Neural Systems and Rehabilitation Engineering 28:191-202. DOI: 10.1109/TNSRE.2019.2958679