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Articles

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PRODUCTION AND INVESTIGATION OF THE MECHANICAL PROPERTIES OF POLYPROPYLENE-BIOSILICA COMPOSITES

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ABSTRACT

Polypropylene (PP) as thermoplastic has found use in the production of a variety of items due to its low cost and ease of production. However, its usage is limited to inherent in its mechanical properties. Rice husk which is readily available and underutilize is considered a major source of biosilica (BS) after calcination. Therefore, the incorporation of biosilica into polypropylene resin as a composite will further reduce the cost and improve its properties. This research developed Polypropylene-biosilica composites with varying compositions of BS and their mechanical properties were determined using ASTM standard test methods. The results of the mechanical test showed a significant increase in Young's modulus from131.08 MPa at 0wt% to 224.86 MPa at 20wt% and flexural modulus from 1055 MPa at 0wt% to 1936.36 MPa at 20wt%. However, a decrease in tensile strength from 30.61 MPa at 0wt% to 24.78 MPa at 5wt% and percent elongation from 24 at 0wt% to 12.4 at 5wt% was recorded. Also, a decrease in Impact strength from 0.26 J at 0 wt% to 0.225 J at 5wt% and hardness value from 23.46 HV to 22.00 HV was observed. It was deduced from the results that polypropylene-biosilica composite is suitable for applications where rigidity is required.

1 INTRODUCTION

Engineering materials such as cast iron and alloyed steel that exhibit good mechanical properties have some setbacks on the account of heavyweight, high cost and non-degradability. Technological advancement is geared toward the use of materials that possess a good strength-to-weight ratio in engineering materials which has led to extensive research and development in the field of composites [1]. Reinforced composites with inorganic fillers enhance their mechanical and physical properties [2]. However, these composites have some setbacks because of their non-degradability and eco-friendly [3]. For this reason, natural fibres provide an alternative as reinforcement fillers in thermoset, thermoplastic and elastomer. Particulate composite reinforced with polymer exhibits superior mechanical properties to unreinforced resin [4]. The addition of biofillers with low-density particulate materials like rice husk ash, jute and bones combine into thermoplastic to form polymer composite reduces dependence on the use of mineral particles and could achieve a good strength-to-weight ratio [5]. Organic fillers have become an alternative to traditional inorganic fillers due to their low densities, very low cost, non-abrasiveness, recyclability, biodegradability and renewable nature [6].

Recently, there has been growing environmental concern and the need for sustainable development, which has raised interest in using natural fibres as reinforcement in polymer composite to replace synthetic fibres such as glass [3]. In Nigeria, agricultural by-products such as rice husk, which are in abundance, are not adequately utilized for engineering applications. Rice husks constitute environmental pollution due to its resistance to decomposition in the soil and low nutritional value if used as animal feed [7]. Therefore, the utilization of Rice husks as fillers would help in overcoming these challenges. Rice husk contains 86% - 97% amorphous silica when calcined to ash [8]. The presence of high silica content in rice husk ash makes it a valuable material for use in industrial applications [9]. Hence, this makes it a good candidate for the development of cheap, lightweight and environmentally friendly composite [10]. This research aims at utilizing rice husk by incorporating it into a Polypropylene matrix to improve its mechanical properties.

2 MATERIALS AND METHODS

2.1 Materials and Methods

The materials used for this experiment include rice husk weighing about 3.5 kg sourced from a local mill in Kura, Kura Local Government Area of Kano State, Nigeria, portable water, 1M dilute hydrochloric acid (HCl), distilled water, polypropylene homopolymer with density 0.9 g/cm$^{3.}$

The equipment used includes an aluminium pan of 700 mm^3 volume capacity; a Muffle electric furnace, Carbolite Technology with model number CWF and a capacity of 1100 °C. Heating drying oven, model DHG-9053A with a capacity of 900 °C. A measuring cylinder of 200 ml capacity. Municipal 4 X-Ray Fluorescence (XRF), the XRF Epsilon analytical spectrometer (Model DY1055) designed for elemental analysis of a wide range of samples; a mettle balance with model number AT400 and a precision of 0.0001 g. An Allen Bradley two-roll milling machine with number 0183; compression moulding machine Model M. Metal mould made from mild steel with a dimension of 120 mm × 120 mm. Hounsfield Monsanto tensometer type W, with model number 9875. A 100 kN Universal Testing Machine; a MicroVickers Hardness machine (model MV1-PC), Charpy Impact Testing Machine.

2.1.1 Preparation of biosilica and composite

Rice husk was collected from a milling plant in Kura Local Government Area of Kano State, Nigeria. It was washed to remove sand particles and dust. The clean Rice husk was leached with 1M HCl by heating it in an oven at 70 °C for three hours. Thereafter, it was washed thoroughly with distilled water and air-dried. The sample was calcined into ash in a furnace at about 700 °C for six hours.

Composite preparation involves compounding the constituent substances (polypropylene and biosilica) and pressing the mixture. The formulation of the composite was in weight percent as shown in Table 1.

Table 1. *Formulation of composite*

Sample ID	Polypropylene (wt%)	Biosilica (wt%)
A	100	0
B	95	5
C	90	10
D	85	15
E	80	20
F	75	25

The compounding process was done by two-roll milling to mix and ensure the homogeneity of the mixture. The milling machine was switched on and set for preheating at a temperature of 180 °C for one hour. The speed of the front and rear rolls of the machine was set at 40 and 30 rpm respectively. It was ensured that the clearance between the rolls was minimal. Mixing was done in between the roll by the rollers, and manually turning the mixture was done to achieve good dispersion. The final mixture was then transferred quickly into a mould to avoid heat loss. The mixture was then compressed for two minutes without pressure to stabilize and allow trapped air to escape. The pressure was then raised gradually to 50 bar at 150°C and maintained for eight minutes. These parameters were chosen carefully to avoid degradation of the sample. Thereafter, the mould was removed from the machine and allowed to cool with its content to room temperature. The same procedure was repeated for the remaining four samples.

2.1.2 Testing of mechanical properties

Tensile Test: The test was conducted as per ASTM D3039 using a specimen of dumbbell shape with a width of 10 mm, length of 100 mm and thickness of 3 mm [11]. Two fine marks were made on the samples with a distance of 40 mm apart as the gauge length. A crosshead speed of 5mm/min at room temperature was used. The sample was mounted on the tensometer and the mercury indicator was set. It was ensured that the ends of the test piece were fitted into the grip of the tensometer. The grip was held between the tension head and the operating screw. The force applied to the specimen was transmitted to the chart roller which is attached to a graph paper. Turning of the operating handle leads to a gradual increase of the load at the middle span until a fracture occurs. The force and extension were obtained from the load and extension curve from the graph paper. Two specimens from each composition were used. Figure 1 shows two samples of the composite materials cut into the dumbbell shape for tensile testing.

***Figure 1**. Samples for Tensile Testing*

Flexural Test: Flexural test was conducted according to ASTM D 790-10 Standard Test Methods [11]. The composite sample was cut to 100 mm by 30 mm by 3 mm dimensions using a hacksaw. The experiment was performed with a three-point fixture where samples fracture in the middle. The sample was placed horizontally over two points of contact (lower support span). A lever was gradually pulled down on the sample through one point of contact (upper loading span) until the sample failed. The flexural force that fractures the sample and the deflection was recorded from the machine scale. Two specimens from each composition were used for this test.

Toughness Test: The test was carried out according to ASTM D6110 standard method [11]. The specimen was cut to 100 mm by 10 mm by 5 mm dimensions using a hacksaw. A V-notch of 1.5 mm deep was cut in the middle of the specimen to provide an area of stress concentration for crack initiation. The hammer was raised and the gauged length was adjusted to zero reference position. The specimen was placed horizontally between the two anvils of the machine with the notch away from the hammer. The swinging pendulum harmer was released from a fixed height to strike and fracture the specimen. At the point of fracture, the energy required to break the specimen by a single impact was recorded from the machine scale. The energy value is a measure of the toughness of the sample. Two specimens from each composition were used to measure the impact test.

Hardness Test: The test was carried out using a micro Vickers hardness machine and conducted as per ASTM E 384-17 standard methods [12]. The specimen dimensions used for the test were 10 mm x 10 mm with 3 mm thickness. The Vickers machine was switched on and the specimen sample was placed on the anvil of the machine. It was ensured that the diamond indenter in the form of a pyramid was on the surface of the sample. Ten (10) kgf was selected as the appropriate load. Thereafter, the test button was pressed and there was an automatic indentation of 30 seconds on the specimen. Reading was taken directly from the dial gauge at the end of the indentation. An average of three points was taken for each composition.

3 RESULTS AND DISCUSSION

3.1 Chemical Analysis

The chemical analysis of rice husk ash was carried out using X-Ray Fluorescence (XRF). Table 2 shows the chemical composition of various oxides from the analysis of the rice husk ash. From the table, it can be seen that silicon dioxide (SiO_2) otherwise known as Silica is the constituent with the highest percentage composition (92.8%) followed by sulphur oxide (SO_3) at 2.40% and ZrO_2 being the least constituent oxide (0.01%) in the composition.

From the result of the chemical composition of rice husk ash in Table 2, the XRF analysis result reveals silicon dioxide (SiO_2) otherwise known as Silica is the constituent with the highest percentage composition (92.8%) followed by thirteen oxides components as impurities. The high percentage of silica in the rice husk ash may be attributed to the treatment of rice husk with HCl (calcination), studies in literature have shown that calcination improves silica content[13]–[15]. This finding shows that rice husk is a good source of silica which is an important mineral that can be used as filler in polymer composite as observed by [16].

Table 2. *Chemical analysis of rice husk ash*

Components (Oxide Element)	Composition (%wt)
SiO_2	92.8
SO_3	2.4
K_2O	1.43
CaO	1.4
Fe_2O_3	0.8
Cr_2O_3	0.23
MnO	0.21
TiO_2	0.12
CuO	0.058
ZnO	0.055
BaO	0.0098
V_2O_5	0.008
Al_2O_3	0.002
P_2O_5	0.001
MgO	0.001

3.2 Mechanical Properties of Polypropylene-Biosilica Composite

The results of ultimate tensile strength (UTS) tests conducted on the composites are presented in Figure 2.

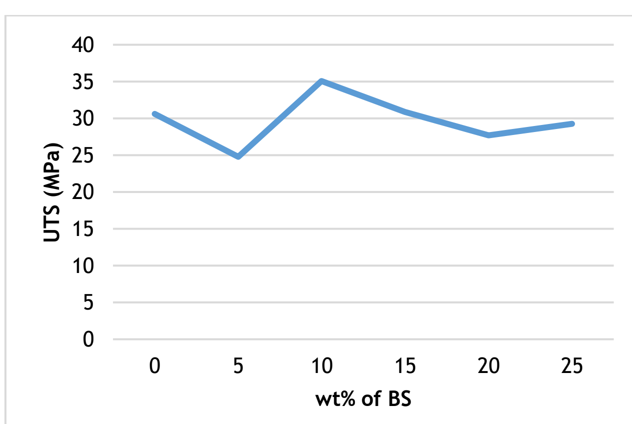

Figure 2. *Variation of UTS with wt% BS additions*

From Figure 2, it can be seen that when the pure polypropylene (0wt% loading of BS) was tested, its UTS was found to be 30.61 MPa, this agrees with what is documented in literature as the UTS of pure polypropylene at room temperature [17]. When BS loading in the composite was at 5wt% it was found that the UTS had dropped to 24.78 MPa. A further increase in the BS loading to 10wt% showed that the UTS of the composite increased to 35.07 MPa. As can be observed, there seems to be an oscillatory pattern to the UTS of the composite as the BS content is gradually increased, however, the average UTS for composites with BS loading of 0wt% to 25wt% hovered between approximately 28 and 30 MPa. This shows that BS has a minimal effect on the UTS of PP, this is corroborated by the findings of [18] who also found that the UTS of their PP composite declined as the biosilica was increased even though they used a different variety of rice husk ash. This finding shows that if PP is to be used to manufacture an object whose desired UTS is supposed to be a bit higher than the UTS of commercially available PP, then a BS load of about 10 wt% is most appropriate.

The overall decrease in the tensile strength may be attributed to the weak interfacial bonding caused by the hydrophobic nature of the PP matrix and the hydrophilic nature of BS filler, resulting in the inability of the BS filler to transfer stress from the matrix. A similar observation was reported by [19] where the addition of inorganic silica filler in polypropylene showed no significant change in the UTS and the maximum value obtained was less compared to BS filler. The increase in the tensile strength at 10 wt% BS loading may be due to the stability of reinforcement to support stresses transferred from the polymer matrix.

The Young's modulus of the composite samples with varying compositions of biosilica obtained by experimentation is presented in Figure 3.

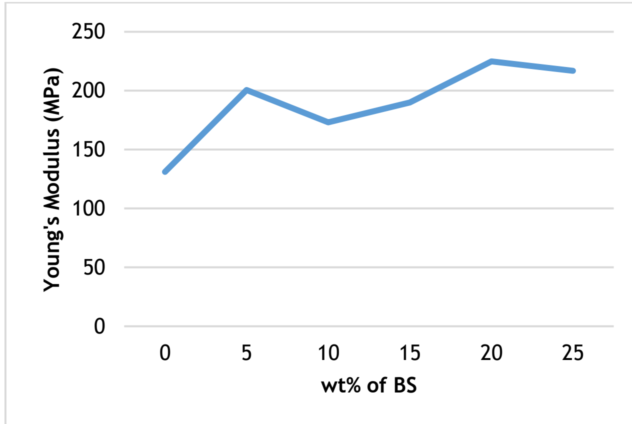

Figure 3. Variation of Young's modulus with wt% BS addition

Looking at the data for the Young's modulus with respect to the weight percent of BS in the composite samples as presented in Figure 3, it can be seen that the Young's modulus of the composite material increased with an increase in BS loading up to 5% and slightly decreased with an increase in loading from 10% to 15%. An increase in the value of Young's modulus was noticed with an increase in the loading of the BS to 25%. The maximum and minimum value of Young's modulus is 224.86 MPa at 20 wt% loading of BS and 131.08 MPa at 0 wt% loading respectively. From the data presented in figure 3, it can be seen that there is a general increase in the Young's modulus of the composite material as the BS content is increased. This trend has been described in similar studies and this is because filler particles of high modulus and aspect ratio increase the modulus of the composite [20], [21]. This shows that a component made of this composite material that has a higher content of biosilica will be able to resist plastic deformation better. Therefore, it can be stated that polypropylene-biosilica composite with a high content of biosilica is most suitable for use in the manufacture of materials that need to resist plastic deformation. It is worthy of mention that the reason why there was a decrease in the young modulus of the composite between 5-10% addition of BS cannot be explained. Also, such trend has not been noted in literature.

The percentage elongation of the composite samples with varying compositions of biosilica obtained by experimentation is presented in Figure 4.

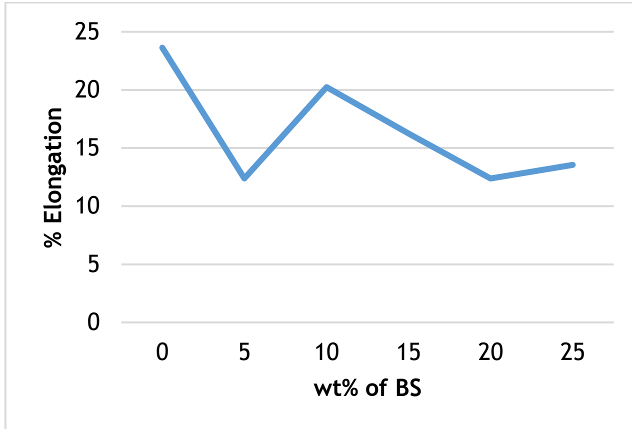

***Figure 4**. Variation of percentage elongation with wt% BS addition*

As can be seen from the data presented in Figure 4, there is a general decrease in the percentage elongation of the composite as the BS content of the composite is increased. At 5 %wt BS loading, the elongation of the PP decreased and as the BS loading was increased to 10 %wt there was a slight increase in the elongation. The value of the percentage elongation gradually decreased with the increase of BS loading from 15% to 25%. The maximum value of percentage elongation of the composite material is 24% at 0% composition and the minimum value is 12.4 at 5% and 20% BS loading. The average decrease in percent elongation with an increase in BS content of the composite might be attributed to the stiffness or rigidity of the composite caused by friction between the BS particles and the polypropylene composite matrix as observed in literature [18], [19]. This finding reinforces what has been stated earlier that biosilica increases the stiffness of PP materials, therefore, this means in instances where PP is to be used to manufacture components that need to be a bit stiffer than the stiffness regular commercial PP provides, then a PP-BS composite can be considered. However, it must be noted that an increase in rigidity/stiffness makes the material more brittle.

The flexural modulus of the composite samples with varying compositions of biosilica obtained by experimentation is presented in Figure 5.

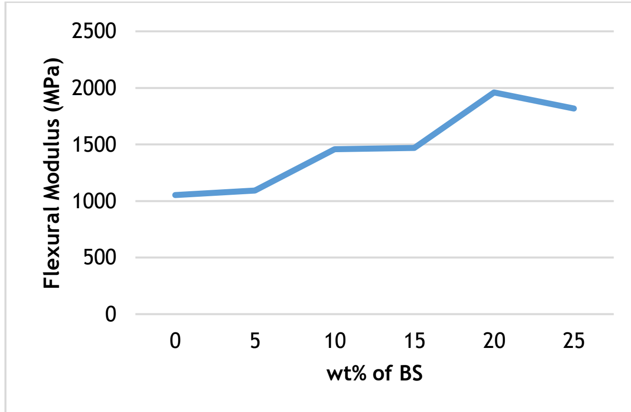

Figure 5. Variation of Flexural modulus with wt % BS addition

The data presented in Figure 5 shows that the modulus of elasticity increases with an increase in BS loading. It can be seen that the modulus of elasticity of the composite material increased from 5% to 20% and slightly decreased to 25% with an increase in the BS loading. That notwithstanding, it can be noted that there is an average increase in the modulus of elasticity of the composite material as BS content is increased. The steady increase in the flexural modulus as biosilica content is increased has equally been observed by other researchers though they used a different rice husk ash [18], [20], [21].

The results obtained are in agreement with the result obtained from percentage elongation at break. The increase in flexural modulus with an increase in BS loading may be attributed to the inability of the polymer chains to move freely because of the restriction caused by filler particles. This implies that BS filler provides stiffness to the polypropylene and therefore it is most suitable in applications where rigidity is required like domestic appliances and automobiles.

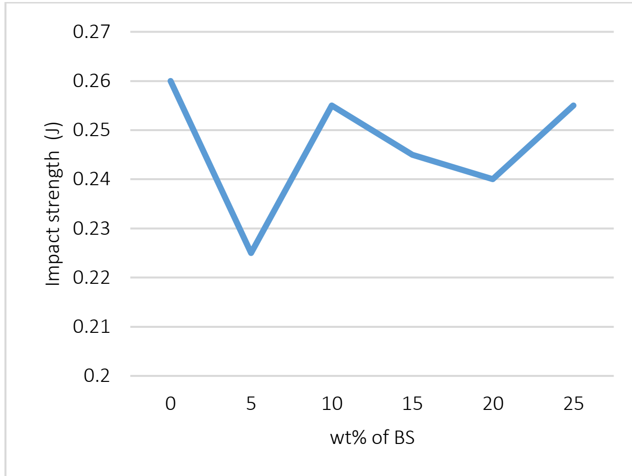

Figure 6. *Variation of Impact strength with wt% BS addition*

From the data of the Charpy impact tests conducted to determine the toughness of the specimens as presented in Figure 6, it can be noticed there is a decrease in toughness as the BS content is increased. [22] also reported that the addition of inorganic silica in PP reduces the toughness and impact strength of the composite. However, the addition of compatibilizers has improved the impact strength. It can be noted that there is a significant decrease in the toughness of the PP when it is formed into a PP-BS composite with 5 %wt BS content. However, at 10 %wt BS loading, the value increases and then starts to gradually decline up until the last trial which is 25%wt BS loading. It was noted that the maximum and minimum value of the composite impact strength was 0.26 J at 0% composition and 0.225 J at 5% composition respectively.

The decrease in impact strength may be attributed to the weak interface between the BS filler and polypropylene matrix which would have stress concentration and generate cracks when there is an impact. The sharp decrease in toughness at 5 wt% BS loading may be attributed to the poor adhesion between the BS filler and the polypropylene matrix. This could be a result of improper mixing resulting in uneven dispersion of the fillers on the matrix.

The result of the microhardness test conducted on the specimens is presented here in Figure 7.

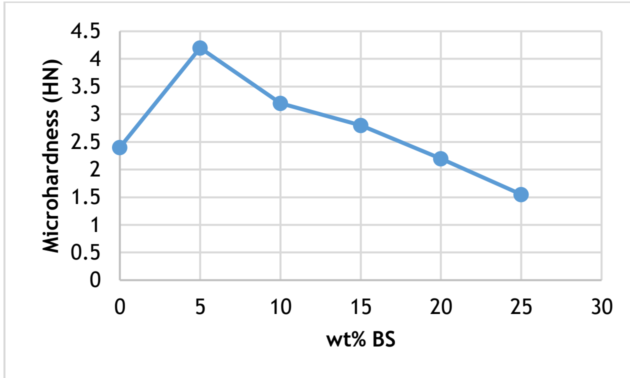

Figure 7*. Hardness Value of the Composite Samples*

From the data presented in Figure 7, it can be seen that as BS loading was increased to 5%, the microhardness spiked and thereafter witnessed a steady decline as the BS loading was continuously increased until the final loading was done. The microhardness value is dependent on the complex surface properties of the material and the condition in which measurements are taken [23]. When this pattern is compared to studies done by other researchers [18], [20], [24], [25] it was found that there is a similarity in the initial increase in the hardness of the composites and then a gradual decrease as the biosilica loading was increased.

The optimum value of hardness was found to be 4.2 at 5% BS loading. This, therefore, implies that the microhardness valve is independent of the biosilica particles.

4 CONCLUSIONS

The research work is centred on the development and mechanical characterization of polypropylene-biosilica composite. It was found that the addition of BS to PP does not significantly change its ultimate tensile strength. It was also found that the addition of biosilica to PP causes an average rise in other mechanical properties of the PP matrix-like Young's Modulus and Flexural Modulus. However, other mechanical properties such as toughness, elongation at break and hardness, and the addition of biosilica to the PP matrix caused an average decrease in these properties.

These findings suggest that BS filler provides stiffness to PP and therefore it is most suitable in applications where rigidity is required like domestic appliances, the automobile and the aviation industry, hence could be a replacement for inorganic silica.

Conflict of interest

There is no conflict of interest between the authors.

Authors contributions

Sudi conducted the laboratory experiments and proofread the write-up, while Mshelia conceptualized the research and authored the research article. Sudi's responsibilities encompassed performing the laboratory experiments, ensuring their proper execution, and meticulously proofreading the write-up for errors and improvements. Mshelia, on the other hand, played a key role in conceptualizing the research, crafting the overall structure, and writing the research article.

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Research and publication ethics

The study is complied with research and publication ethics

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VIBRO-ACOUSTIC ASSESSMENT OF GRAIN GRINDING MACHINE FOR HEALTH RISK FACTORS ANALYSIS

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ABSTRACT

Grinding machines is one of the outcomes of the agricultural sector work process mechanization aimed at reducing tedium and drudgery on the workers and improving overall productivity and production. However, the machinery drive component and mechanical energy are associated with noise and vibration, thereby inducing safety and health concerns for the operators. This study assessed and compared the vibro-acoustic characteristics caused by three different types of grinding machines; electric motor (3HP220V2800HD), diesel (R175A) and petrol (GX160) power drive engines used in grinding shops located in Wadata, Makurdi Local Government Area of Benue State in association with the risk factors to the work environment. The instrumentation design for the grinding machine operations vibro-acoustic characterization was a sound level meter (S844+), a vibrometer (VM-6360), a digital stopwatch (PC-396) and retractable measuring tape (B300-AG). The noise measurements were made at an average seating height of 1.5 m in the operator's work position and the vibrations on the seat surface of the operator. The data obtained were analyzed for noise and vibration occupational risk exposure following the ISO 9612 for acoustics guidelines and ISO 2372 for mechanical vibration and shock. The average mean values for the noise level and vibrations were statistically highest when the diesel power drive engine, followed by the petrol engine, while the electric motor had the least vibro-acoustic effect. In addition, the analysis of the variance test showed that the result obtained for the vibration and noise levels for the three categories of power source drive had p-values less than 0.05, indicating that they are significantly different from zero at a confidence level of 95%. The findings of this study mandated that all operators of the machinery under investigation wear personal protective equipment (PPE).

1 INTRODUCTION

Grinding machine is one of the sustainable developments of agricultural mechanization that has benefited the work process in the field of food processing in operator's efficiency, worktime reduction, facilitation of production activities and increased productivity [1],[2]. The operation of a grain grinding machine for agricultural production processes involves moving of masses, de-backing, breaking and grinding owing to the mechanical drive components such as the driving unit, rollers, damping units, grinding teeth and the engine (which supply mechanical energy). Grinding machines use the principles of abrasion, compression, attrition/shearing, impact or friction forces for size reduction effect in the processing of agricultural raw materials [3]. This operation causes noise and vibrations from the mechanical system of the grinding machine and the work process. In general, mechanical vibrations and noise generation occur in all machinery as long as there are operating. The dynamic forces produced by machinery are often enormous. The widespread use of agricultural machines for work processes has caused some occupational health and safety problems for machine operators [4]-[6].

The vibration from the machine causes whole-body vibration through the floor and the operator's body indirect or direct contact with the grinding machine. The machine and floor vibrate and may harmonize once their frequency approaches each other. However, unwanted vibrations may be induced by large impulsive forces in machines by unbalanced reciprocating of the machine components, gear misalignment and bearing failures [7]. Then again, the vibration may also be due to the grains being fed into the machine and auxiliary equipment [8]. Operators' whole-body vibration is among the most prevalent ergonomic factors affecting agricultural operators' health and work efficiency [9]. According to studies found in the literature, vibrations witnessed in agricultural work processes are a significant health problem causing hazards [10],[11]. Several researchers showed an association between vibration exposure and health issues like musculoskeletal disorders, fatigue, spinal injury, metabolism issues, and cardiovascular and nervous system risks [12]-[15]. Measurement of the vibration will proffer appropriate ways to reduce them at their sources.

Conversely, while assessing the health and safety of employees, in addition to exposure to chemical substances, dust, heat, musculoskeletal disorders, vibration, and noise in agriculture are other significant risk factors that must be considered [9],[16]-[19]. The average limit to noise exposure by the Occupational Safety and Health Administration for a time-weighted average (TWA) of eight hours duration is 86.1 6.2 dBA and 90.2 5.1 dBA for the National Institute of Occupational Safety and Health [20]. The limit of human exposure to vibration as determined by the International Standards Organization (ISO) and accepted by the National Institute of Occupational Safety and Health (NIOSH) and Occupational Safety and Health Administration on daily exposure to whole-body vibration for action is 0.5 m/s^2, with a limit of 1.15 m/s^2 for the frequency-weighted root mean square acceleration. Bilski [21] labelled noise as a significant hazard in the working environment of the agricultural sector. According to studies, noise emissions from farm machinery are not immediately noticeable, but the cumulative impacts over time [22]-[24]. Noise exposure effects on workers include a rise in stress and discomfort levels [25], decreased operational capacity, hampers work efficiency [26], noise-induced hearing loss [9],[27], hampers concentration [26]. mental imbalance, and degenerative physical illnesses [23],[24]. Additional physical impacts of noise exposure include changes in blood pressure, other cardiovascular alterations, higher attendance at general medical practices, issues with the digestive system, and overall weariness [28]-[30]. The noise level at the operator’s ear during his working day is one of the factors that needs evaluation in production systems that use machinery intensively [22]. It is important to note that the noise levels generated by engines vary considerably among mechanical systems of different machines depending on various factors, including the power drive components [21]. Similar studies found in the literature that assessed occupational exposure in food grinding shops considered only noise exposure [31]-[34]. A Google search of different databases found no literature that focused on the noise level and whole-body vibration assessment caused by food grinding machines. As well, none compared the power sources for their effects on the vibration and noise level in the work environment

Measurement of vibration and noise levels aids in indicating and monitoring the performance of the machine and provides an immediate warning whenever the vibration and noise levels rise above the recommended level for the safety and health of the work environment [35]. Most food grinding machine operators are self-employed, and like other entrepreneurs, they control their working hours because they not aware of the relevant occupational health and safety standards, predisposing them to higher risks of noise hazards. This peculiarity sets them apart from workers in other occupations with high noise potentials [36],[37].

Acoustic engineers objectively characterize vibration and noise exposure in the work environment using noise level meters and vibrometers. The connection between the risk levels due to noise or vibration and stages of health problems is usually determined based on a flexible risk assessment method. The approved guide for the measurements of occupational hazards are found in the international standard organization (ISO 9612 for acoustics severity risk analysis and ISO 2372 for vibration severity risk analysis). The noise and vibration challenges of agricultural work process mechanization in different agricultural sectors has been studied. However, there is no information available that carried out a research on combined noise and vibration challenges of the food grinding machines due to the power drive source and from the standpoint of labour protection. Therefore, this study assessed the operators' occupational whole-body vibration and noise exposure from the power drive sources for the grinding machines used at the grinding shops and interpreted the health severity risk using the established criteria.

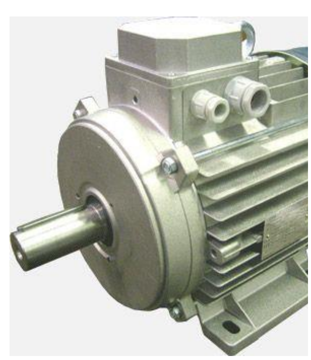
2 MATERIALS AND METHODS

The vibro-acoustic characteristics of the grinding machine assessment were conducted on three categories of power drive sources for the grinding machine used in Wadata, Makurdi Local Government Area of Benue State. The study area was considered from the fundamental circumstances obtainable in Nigeria that mechanization of work processes involving agro-based products has reduced the physically strenuous and repetitive activities involved in the food processing operations and the pre-study observation for this study that the grain grinders are frequently overcrowded and as such continuously work each day. They included the following diesel-powered engine (R175A), electric motor (3HP220V2800HD) and petrol-powered engine (GX160) (Figure 1). The specifications of these engines are presented in Table 1 below. The grinding machines had to be in good functioning order, never had a complete breakdown, never had a major part replaced or repaired, be brand new when purchased, and had been purchased within the past 0–2 years were the criteria for the power drive source selected for this study. The vibration effects highlighted by Hoshi [8] such as imbalance, misalignment/shaft run-out, wear and looseness, were taken care of as measures against these faults were checked during the data collection process.

***Table 1**. Specifications of the three power drive engines*

Power drive source	Model	Rated power (kw)	Speed (rpm)
Electric motor	3HP220V2800HD	2.23	2800
Diesel powered engine	R175A	4.41	2600
Petrol powered engine	GX160	3.60	3000

Diesel powered engine (R175A) [38]



Electric motor (3HP220V2800HD) [39]

Petrol powered engine (GX160) [40]

***Figure 1**. Three categories of power generators for the grinding machines*

The instrumentation design for the data collection in this study were:

A vibrometer - model number VM-6360 (Guangzhou Landtek Instruments CO. Ltd.) was a scientific hand-held measuring device, use to take various assessments of vibrations on machines. It has a frequency range of 10Hz and operates within a temperature range of 0° – 50°.

A sound level meter – model number AS844+ (Neufday Ltd) was an instrument used for acoustic measurement. It is a handheld instrument with a microphone. Its measurement range is between 30 – 130 dB.

A retractable measuring tape - model number B300-AG, was an instrument used to measure distance.

During the evaluation of the physical labor activity, a digital professional (LCD) stopwatch of model PC-396 (Shenzhen super deal Co, Ltd, China) was used to record the duration of the time interval for the job characteristics.

Vibrometer	Sound level meter	Measuring tape	Stopwatch
[41]	[42]	[43]	[44]

Figure 2. *Data collection devices*

This study was limited to the grinding process of the following types of grain; maize, beans, millet, and guinea corn) as they are predominantly ground grains in the locality. These were used to ascertain the associated vibration and noise during the grinding operation. The grains are shown in Figure 3.

Maize Beans Millet Guinea corn

***Figure 3**. grains samples*

The grains were ground to smooth textures by grinding each grain twice. The grinding machines were powered by all three power sources—an electric motor, a gasoline engine, and a diesel engine—but different cutting discs were utilized for each operation. The noise and vibration measurements were simultaneously carried out at the unloaded and loaded (the grains grinding operations) stages. The noise level was measured at an average height of about 1.5 meters corresponding to the average ear level of a seated adult [29],[45]. The vibration was determined on the working seat of the machine operator from the grinding machine. The whole-body vibration was measured as it is the vibration transmitted to the entire body via the sit through the mechanical vibrations of the grinding machine affecting the floor and the operators' sits. Whole body vibration was measured using the vibrometer by placing the vibration meter sensor within the seat pad of the operator, which the operator sits on during the grain grinding process. The vibration rhythm of the effect of the grain grinding operation reflects on the dynamic signal analyzer screen for recording. The measurements were taken and recorded five times at intervals of 30 seconds during the idling and the grains grinding operations stages using the power generators, electric motor, petrol and diesel powered engine for the same grinding machine in each case. The average duration of the grinding process recorded for smooth texture (grinding twice) for the three categories of power drive sources varied as 3.5 min/kg, 4.25 min/kg, and 5.5 min/kg for an electric motor and diesel- and petrol-powered engine grinding machines.

The subsequent calculation of the equivalent energy noise level (*LAeq*), which simultaneously incorporates the intensity and exposure time of the environmental noise, is made possible by various noise level measurements during the assessment period. Obtaining a single value that indicates a consistent noise level in the same total sound energy being produced over a certain period, data received in each work duration interval were calculated to an A-weighted equivalent sound pressure level (*LAeq*). The mathematical formula employed for this is as follows:

$$L_{Aeq} = 10\log_{10}\left[\frac{1}{N}\sum_{i=1}^{N}\left(anti\log\frac{L_{Ai}}{10}\right)\right] \quad (1)$$

where

L_{Aeq} = A-weighted equivalent sound pressure level

L_{Ai} = A-weighted sound pressure level in dB

N = total number of measurements

The computed A-weighted equivalent sound pressure level (*LAeq*) at each of the grinding operations shops assessed was analyzed on typical noise levels scale international standard organization. Noise level and vibration were evaluated following the ISO 9612:2009 (acoustics – guidelines for noise exposure assessment in a working environment) and ISO 2372 (mechanical vibration and shock – evaluation of human exposure to whole-body vibration) [35],[46]. The categories of the noise intensity on the typical noise levels scale are presented in tables 2 and 3 below.

Table 2*. Noise level severity risk level criteria [46]*

S/N	Risk level	Noise level severity Criteria (dBA)
I	Tolerable risk	<80
Ii	Justified risk	>80 - 85
Iii	Unjustified risk	>80 - 87
Iv	Inadmissible risk	>87 - 95
V	Intolerable risk	>95

Table 3. *Vibration severity risk level criteria [35]*

Vibration velocity (mm/s)	Vibration severity criteria
0.28	Good
0.45	
0.71	
1.12	Acceptable
1.80	
2.80	Monitor closely
4.50	
7.10	
11.20	Unacceptable
18.00	
28.00	
45.00	

One-way analysis of variance (ANOVA) was conducted to compare the mean of the noise and vibrations produced during the grain, maize, beans, millet, and guinea corn grinding processes and to determine whether there were significant differences between the groups. These analyses were performed using Microsoft Excel 2016 and the Statistical Package for the Social Sciences (SPSS) 20.0 ($p<0.05$).

3 RESULTS AND DISCUSSION

The descriptive statistics of the vibro-acoustic characteristics of the three categories of power drive sources used in driving the grinding machines were analyzed and presented in table 4. The analysis covered the unloaded and loaded effects of the power drive sources on the seat of the grinding machine operators in the workshops. The result showed that the average mean, standard deviation (SD) and standard error of mean (SEM) of the vibration effect of the diesel-powered source was highest (mean ± SD = 36.02 ± 1.31, SEM = 0.29) mm/s during the unloaded grinding operation of the grinding machine. This was followed by petrol-powered engine (mean ± SD = 20.25 ± 1.26, SEM = 0.28) mm/s and then the electric motor-powered source (mean ± SD = 11.40 ± 0.72, SEM = 0.16) mm/s (Table 4). The vibration values in this study buttressed Jibiri et al. [47] study that the ambient vibrations from a power generating source can be translated to a noticeable vibration effect on the floor and any other thing in contact with it and hence contribute to the noise level. The results of vibration translated from the machine to the seat of the grinding machine operator in the workshop and the noise generated when the machines obtained during the grain grinding process showed that the highest vibration effect was observed when diesel powered engine was the source of driving force for the grinding machines, whereas the electric motor use observed the lowest vibration effect.

Table 4*. Vibration characteristics of the power drive sources assessed*

Characteristic job operations	Power drive sources	Min	Max	Mean ± SD	SEM
Unloaded grinding machine	Electric motor	10.60	13.50	11.40 ± 0.72	0.16
	Petrol powered engine	18.10	22.70	20.25 ± 1.26	0.28
	Diesel powered engine	34.10	39.20	36.02 ± 1.31	0.29
Loaded with Maize	Electric motor	9.00	11.30	10.18 ± 0.66	0.15
	Petrol powered engine	14.30	25.90	21.48 ± 2.35	0.53
	Diesel powered engine	29.90	50.80	35.88 ± 6.13	1.37
Loaded with millet	Electric motor	7.20	10.80	8.55 ± 0.93	0.21
	Petrol powered engine	14.20	22.10	16.56 ± 2.07	0.46
	Diesel powered engine	21.60	35.40	25.95 ± 3.34	0.75
Loaded with guinea corn	Electric motor	7.70	10.10	9.09 ± 0.58	0.13
	Petrol powered engine	12.20	18.60	15.45 ± 1.67	0.37
	Diesel powered engine	21.40	30.40	24.75 ± 2.26	0.50
Loaded with beans	Electric motor	9.60	13.00	11.09 ± 0.79	0.18
	Petrol powered engine	14.50	19.20	16.64 ± 1.26	0.28
	Diesel powered engine	32.00	44.60	38.73 ± 3.86	0.86

Note: Min = Minimum, Max = Maximum, SD = Standard deviation, SEM = Standard error of mean

During the unloaded grinding operation of the grinding machine, the diesel-powered engine source produced the maximum noise level (mean SD = 110.88 2.87, SEM = 0.64), followed by the petrol-powered engine (mean SD = 92.37 2.98, SEM =

0.67). This result followed a similar trend as the vibration. When the electric motor-powered source was engaged, the lowest A-weighted equivalent sound pressure level was recorded throughout the grinding operation of the grinding machine (mean SD = 88.46 3.43, SEM = 0.77) (Table 5). The values obtained in this study buttress the outcome in previous studies found the works of literature that unloaded machines could impose high noise levels in the work environment [29},[48]-[49]. The observation made for the A-weighted equivalent sound pressure level calculated showed that the noise levels generated during the grain grinding process were highest when diesel-powered engines were used to drive the grinding machine. The method of functioning of the petrol and diesel engines can explain the higher A-weighted equivalent sound pressure level calculated from those engines. As reciprocating engines, gasoline and diesel engines generate power through the mechanical motion of their piston-crank systems. Pressure variations caused by the exothermic reaction of hot expanding gases (high temperature and pressure oxidized fuel) in the combustion chamber drive a rotating electric generator for generating driving power. Through the air, motion and vibration generate a series of alternating compression and rarefaction phases. This study agreed with work in the literature that the vibration of the generator frame also affects the surrounding air, which is heard as noise [50].

The survival and achievement of a workplace objective require a healthy workforce, which can only be assured when the environment in which it operates is healthy and safe. Occupational vibro-acoustic characteristic exposure determined by the International Standards Organization has a diverse effect on the occupational health of the exposed workers including noise-induced hearing loss, high blood pressure, heart disease, stress, hand-arm vibration syndrome, fatigue, and loss of balance As such, it is being guided by rules stipulated by the Occupational Safety and Health Administration and NIOSH on the limits to which a worker should be subjected for a particular duration of unsafe and safe usage exposure. Occupational diseases that affect workers that as documented in studies include physical pain, mental agony, and disability which may lead to some deprivation that could continue for the rest of the victim’s life, loss of earning power, loss of leisure activities, extra expenditure for services he can no longer render for himself, loss of family affection and possible loss of life [51],[52]. The health risk factors analysis of the vibration characteristics of the power drive sources assessed through the use of standard typical evaluation criteria zone vibration magnitude (mm/s) when compared to the ISO 2372 for vibration severity risk level criteria for monitoring and machinery protection systems is to ensure the health and continuous operation of the plant machinery revealed 100% unacceptable vibration risk level. This may be due to the portable stand used to fix the power drive source and the grinding unit.

Table 5*. Acoustic characteristics of the power drive sources noise assessed*

Characteristic job operations	Power drive sources	Min	Max	Mean ± SD	SEM
Unloaded machine	Electric motor	83.60	96.90	88.46 ± 3.43	0.77
	Petrol powered engine	86.00	97.90	92.37 ± 2.98	0.67
	Diesel powered engine	104.20	114.70	110.88 ± 2.87	0.64
Loaded with Maize	Electric motor	96.50	104.70	100.58 ± 2.42	0.54
	Petrol powered engine	95.40	103.30	99.20 ± 2.19	0.49
	Diesel powered engine	91.40	99.70	94.34 ± 2.23	0.50
Loaded with millet	Electric motor	85.40	99.90	94.28 ± 4.67	1.04
	Petrol powered engine	89.30	98.90	91.18 ± 2.13	0.48
	Diesel powered engine	92.80	108.10	98.95 ± 4.74	1.06
Loaded with guinea corn	Electric motor	86.90	99.20	95.15 ± 3.48	0.78
	Petrol powered engine	89.80	99.10	91.65 ± 2.10	0.47
	Diesel powered engine	94.70	101.00	98.31 ± 1.91	0.43
Loaded with beans	Electric motor	88.80	94.50	91.42 ± 1.47	0.33
	Petrol powered engine	92.30	104.40	97.33 ± 2.99	0.67
	Diesel powered engine	93.90	101.50	97.51 ± 2.32	0.52

Work operations in a work environment with continuous noise intensity levels are time-bound. The noise level intensity with respect to the recommended noise exposure duration varies, and that determines the level of risk involved. The evaluation of the noise exposure level in this study was done using an 8-hour time-weighted average recommended exposure limit for occupational noise exposure by NIOSH. Monitoring and equipment protection systems, noise level at the grain grinding shops was analyzed and presented in Table 6 to ensure the safety and ongoing functioning of the plant's machinery. The results showed that the noise levels created by the machinery during grinding grain were unjustified risk levels at 58.33% of the examined grain grinding establishments, followed by inadmissible risk levels at 40.63% of the dwellings. The ranges of noise levels obtained were all above the tolerable and justified danger noise levels criteria. The measured noise level analyzed in this study and categorized as an unjustified risk of noise exposure following the international standard organization guidelines for noise exposure assessment in a working environment implies a conscious disregard of a perceived significant risk. The noise level exceeded the workers' tolerance risk capacity; therefore, the grinding shops were unsafe for the workers' bodies. Considering that the NIOSH recommended exposure limit for occupational noise exposure is 85 dBA for an 8-hour time-weighted average, the inadmissible risk (> 87–95 dBA) is an unsafe condition for a workplace as the effect of noise exposure is time-limited [53]. From the results of the vibro-acoustic characteristics of the three types of power drive sources used to drive the grinding machines above, machines generate noise from structure vibration and noise radiation during the cutting processes as a result of the mechanical resonance frequencies of the machine frame and rotating grinding cutter tool. Because there is an industrial regulation protecting workers from noise pollution, it is possible to assess noise pollution and its impact on human health [54]. The recorded values for the three types of power drive sources for the grinding machines evaluated in this study revealed that unloaded when compared with the Nigerian Environmental Standards and Regulation Enforcement Agency's (NESREA) recommended continuous exposure limit of 85 dBA, has noise exposure level potentials for occupational injury in the work environment as the noise level in the three types of power drive sources were higher than 85 dBA. Occupational noise exposure level beyond the maximum permissible noise level for health and safety workers poses a big challenge to the workforce or human resources of any nation as occupational health and safety are interrelated and complementary and, as such, plays an intricate and vital role in the workers' life. This observation was similar to the results obtained by other researchers that assessed the intensity of unloaded machines on the noise level in the work environment [29],[48]-[49].

Table 6*. Categories of the Noise level severity risk at the grinding Shops*

Risk level	Frequency (n)	Percentage (%)
Tolerable risk	0.00	0.00
Justified risk	0.00	0.00
Unjustified risk	280.00	58.33
Inadmissible risk	195.00	40.63
Intolerable risk	5.00	1.04

The analysis of variance (ANOVA) test was performed to examine the effect of power drive sources, such as electric motors, gasoline engines, and diesel engines, on the vibration by comparing the mean square against an estimate of the experimental error. It also emphasized the statistical importance of the effects of each power drive source. The vibration results for the three power drive source categories have p-values less than 0.05 at a 95% confidence level, indicating that they are significantly different from zero (Table 7).

Table 7*. Analysis of variance for the effect of the three power drive sources on noise level*

Characteristics	Representation	Sum of Squares	*df*	Mean Square	*F*-value	*p*-value
Noise	Between Groups	6094.64	2	3047.322	240.239	0.00
	Within Groups	6050.54	477	12.685		
	Total	12145.18	479			

The impact of power drive sources on noise level was examined using a variance analysis, and the statistical F-value for this study was 28.50. The means of the groups are significantly different from each other, since the p-value is less than 0.05 (Table 8). This result indicates that the energy drive sources.

Table 8. Analysis of variance for the effect of the three power drive sources on vibration

Characteristics	Representation	Sum of Squares	*df*	Mean Square	*F*-value	*p*-value
Vibration	Between Groups	34126.79	2	17063.393	1038.28	0.00
	Within Groups	7839.17	477	16.434		
	Total	41965.95	479			

4 CONCLUSION

The operation of a grain grinding machine for agricultural production processes is one of the mechanizations of work operations in food processing industries through the employment of improved tools or equipment to reduce tedium and drudgery on the workers and improve overall productivity and production. This has been found to cause noise pollution in the workplace, which is a health threat to the workers. The vibro-acoustic characteristics of the grinding machine assessment were conducted on three categories of power drive sources for the grinding machine including diesel-powered engine (R175A), electric motor (3HP220V2800HD) and petrol-powered engine (GX160) showed that vibration and noise levels from the grinding machines were high in the three different types of power drive sources considered. The diesel power drive engine produced the loudest noises and the most tremors, followed by the gasoline engine and the electric motor. The result for the vibration and noise levels for the three categories of power source drive had p-values less than 0.05, showing that they are substantially different from zero at a 95% confidence level, according to the analysis of the variance test. Analysis of the whole-body vibration and the noise exposure of the operators using the established vibration and noise exposure standard for limit in the work environment showed that the whole-body vibration and the noise emission levels of the operators in the grinding shops are unsafe for human health, which was a risk concern According to this study's results, personal protective equipment is recommended for the workers in the grinding shops, irrespective of the categories of power drive sources for the grinding machine.

Conflict of interest

There is no conflict of interest between the authors.

Authors contributions

Conceptualization and the design of the framework was carried out by Amine D.J; Azodo A.P identified the gap in the literature that the work intended to bridge, drafted and revised the manuscript; data collection and analysis was handled by Owhor S.C. the three authors were substantively involved in the manuscript proofreading.

Research and Publication Ethics

This study was approved by ethics and research committee of Federal University of Agriculture, Makurdi with approval code 15/32933/UE, March, 2021.

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SENTIMENT ANALYSIS IN SOCIAL NETWORKS OF HEALTH INSTITUTIONS

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ABSTRACT

Twitter, a communication platform that creates a social impact; it conveys the messages of non-profit organizations to the masses and the emotions of the masses to non-profit organizations. This research; It aims to examine Twitter posts about health-related non-profit organizations, to determine the emotional states about these institutions on social media and to measure these feelings.

Sentiment analysis about WHO, ILO, IOM, UNICEF, FAO, Red Cross, UNDP and UNHCR were carried out using the R program. The tweets used in sentiment analysis were collected by approval of Twitter API. During the study, a total of 310,341 tweets were collected in three periods, November 2019, May 2020 and October 2020. Tweets are classified according to 10 different emotions. One of the main findings of the study is that “positive”, “trust” and “anticipation” feelings are at the top of the tweets shared about these institutions under normal conditions and crisis conditions. Sentiment consistency was tested with Friedman test for each institution after emotional analysis was performed in all institutions ($p<0.05$). In all institutions except FAO, a significant relationship was found between the emotion medians of the feeling of “fear” according to the periods. However; according to the results of the sentiment analysis, an increase was observed in the “fear” feeling of the institutions during the pandemic period.

This research; non-profit international organizations that make environment, health and sustainable development a principle; provides a conceptual framework for understanding when and why follower behaviour originates. Thus, it can enable organizations to realize their missions, create meaningful support in times of crisis, increase benefit and awareness, facilitate decision-making, and increase communication and interaction.

1 INTRODUCTION

Public health; It combines various measures to promote health, prevent disease and extend the lifespan of the population. It targets all populations, particularly through the formulation of public policies regarding the determinants and priorities of health, by monitoring their health status and improving the health conditions of the population. Needs are determined by priorities and preferences [1]. Priorities and choices result in different ways to guarantee appropriate access to health care, promote health, and prevent disease. The main purpose of non-profit organizations (NPO), which aims to provide this and is established to meet the needs of the society in various issues in general, is to realize their vision and mission. In this context; institutions need to maximize their impact on society. The success of NPO's efforts is increased by providing social information to raise awareness of its aims and interacting with its followers and receiving support and feedback from potential donors and volunteers for its planned programs. This to ensure that; It needs interaction with its target audiences and awareness of the society [2]. The fastest and most effective way to increase social impact and community awareness is to use social networks correctly [3]. This research; The aim of this study is to analyse the Twitter shares of non-profit institutions that work on health and to determine the emotional states of these institutions on social media, and to measure these feelings, with sentiment analysis, which is a text mining method. Research; It was conducted to evaluate the use of social media under normal conditions and in periods of international crisis related to non-profit international organizations whose main and / or secondary goals are health. In this context; It includes the evaluation of the emotional response of social media to social events at different times and in different situations, on the basis of non-profit organizations that aim to improve health. The influence of social media in health promotion is an important tool to determine people's tendencies. A comprehensive process evaluation was made for the social media of the institutions within the scope of the research during the COVID-19 pandemic period.

2 METHODS

In the scope of the research; From a social marketing point of view, using technology and social media, and applying it on Twitter, tweets collected by Sentiment analysis method were classified as positive, negative or neutral. Sentiment analysis is the process of determining whether a text is positive, negative, or neutral. Here, for the purpose of this analysis, the “syuzhet” package has been studied. This library uses the NRC sentiment dictionary to classify tweets after text preprocessing. NRC emotion dictionary; is a list of words and their associations with eight emotions (anger, fear, anticipation, confidence, surprise, sadness, joy, and disgust) and two emotions (negative and positive). Sentiment Analysis of Institutions; Process evaluation was carried out as a comprehensive evaluation strategy for social media during the COVID-19 pandemic period. In this context; Within the scope of the study, tweets were taken three times to see how the reflections of the COVID-19 pandemic, which especially affected the world, affected the sentiment analysis of these eight institutions. “What is the sentiment score of Twitter posts about institutions?”, “What are the most frequently mentioned topics in these posts?” and “What is the change in mood scores and most frequently mentioned topics after the COVID-19 pandemic?” questions were addressed in the research. 8 non-profit organizations in the research; Sentiment analysis was conducted before and after the COVID-19 pandemic. In addition to sentiment analysis, comparisons of the most frequently used words by Twitter users who mentioned these institutions during the research periods were also included, and these words with high frequency were visualized with a word cloud.

2.1 Selecting Research Dataset

The data provider universe of the research consists of Twitter searches of some non-profit international organizations whose main or secondary field of study is health and accepted as a centre in their fields. These international organizations are the World Health Organization (WHO), United Nations Food and Agriculture Organization (FAO), United Nations Development Program (UNDP), United Nations International Children's Emergency Fund (UNICEF), International Labor Organization (ILO), International Organization for Migration (IOM), the International Committee of the Red Cross (ICRC), the United Nations High Commissioner for Refugees (UNHCR). International organizations in the research were included in the research according to the number of Twitter followers.

Sentiment analysis of WHO, ILO, IOM, UNICEF, FAO, Red Cross, UNDP and UNHCR was performed using version 4.0.2 of R Studio program (R statistical software, www.R-project.org). In this research, a "dictionary-based" approach was used. Dictionary-based approaches are used to measure the overall emotions around the text in question [4]. Tweets to be used in sentiment analysis; It was collected by communicating with the Twitter API linked to the Twitter account. During the study, 310,341 tweets were collected. Within the scope of the study, three tweets were taken to see how the reflections of the COVID-19 pandemic, which affected the world, affected the sentiment analysis of these eight institutions. The first tweeting process; In November 2019, the second was shot in April-May 2020, a period when the impact of the COVID-19 pandemic on social media was intense, and the third was shot in October 2020, a period when the number of cases was increasing. In November 2019, 70,932 tweets were collected. From the Twitter API 6339 tweets about WHO, 5931 tweets about IOM, 8662 tweets about ILO, 10,000 tweets about FAO, 10,000 tweets about Red Cross, 10,000 about UNDP, 10,000 tweets about UNHCR, 10,000 about UNICEF tweeted. A total of 114,756 tweets were collected in May 2020. One of the important dates for the COVID-19 pandemic is January 2020, when the virus began to spread across the continents. The data extraction process carried out in April-May was repeated, limiting it to include tweets from 1 January 2020. From the Twitter API 14,816 tweets about WHO, 5483 tweets about IOM, 16,454 tweets about ILO, 10,898 tweets about FAO, 17,000 tweets about Red Cross, 16,105 tweets about UNDP, 17,000 tweets about UNHCR, about UNICEF 17,000 tweets were shot. In total in October 2020; 115,909 tweets were collected. According to WHO data, a new peak has occurred in the COVID-19 pandemic, with more than 300,000 new cases in 190 days (WHO 2020). In this context, the third group of data extraction is limited to the tweets from August 2020. The number of tweets requested from the Twitter API for each institution has been determined as 17,000. From the Twitter API 17,000 tweets about WHO, 6111 tweets about IOM, 13,887 tweets about ILO, 15,140 tweets about FAO, 14,959 tweets about Red Cross, 17,000 tweets about UNDP, 14,812 tweets about UNHCR, about UNICEF 17,000 tweets were shot.

2.2 Sentiment Analysis with R

Analysis of Twitter data with R program; It starts with extracting text from Twitter. The extracted text is then transformed to create a document term matrix. After this conversion process, the most frequently spoken words on Twitter are obtained in the matrix structure. Word cloud is used to present important words in documents [5]. Before probing a data on Twitter using the API, Twitter authentication needs to be done using an application created by Twitter. twitteR, ROAuth, tm, wordcloud, ggplot2, RColorBrewer, stringr, plyr, SnowballC, syuzhet packages are the main packages used in sentiment analysis. The "searchTwitter ( )" function is used to access and search the data [5]-[16]. This function belongs to the twitteR package and enables searching Twitter based on a given search string [17]. In the research; keywords "World Health Organization" for WHO, "unicef" for UNICEF, "undp" for UNDP, "unhcr" for UNHCR, "fao" for FAO, "ilo" for ILO, "iom" for IOM, and Red Cross It is designated as "red cross". Search words were chosen based on their international abbreviations, except WHO and Red Cross. Since the abbreviation of WHO is frequently used both as a relative and interrogative pronoun, the full name of the institution was preferred instead of the abbreviation. The open version of Red Cross was preferred because it is generally more known than the international abbreviation of red cross. The R program used; It is widely used in text mining studies. When working with R, the related packages must be downloaded first and then the downloaded packages must be called. First, the tweets are analysed using the text dictionary and the sentiment values of the sentence (positive, negative and neutral) are calculated. Due to the noisy nature of tweet data, tweets about COVID-19 often included similar words. Each dataset contains its own identifying information about users, the content of their tweets, including hashtags and hyperlinks, and the relationships between users (retweets, mentions, and replies).

2.3 Text Preprocessing

The text must be preprocessed before the tweet data can be analysed. In the preprocessing (ontology-based normalization process) step, first, a cleaning process; spell checking, changing abbreviations, removing duplicated characters, and grammar rules [18]. Text data can be white spaces, punctuation, stop words, etc. contains. These characters do not carry much information and are difficult to process. To ensure that the handled data is clean; convert text to lowercase (words such as “write” and “write” are considered the same word for analysis), remove numbers, remove English stop words (for example, “the”, “is”, “of”, etc.), remove punctuation (eg “,”, “?” etc.), removing excess spaces, root finding operations are carried out [16]. The "Tm" package in R is used to perform this operation. The main structure used to manage documents in TM is called Corpus, which represents a collection of text documents. The modification of the words in the tweets is done by the mentioned cleaning process. The purpose of using the “tm” library includes rooting words, removing stop words, and other methods as noted. Basically, all conversions work on single-text documents. Preprocessing was done by removing noisy data from tweets, irrelevant comments, Twitter usernames starting with @, URLs starting with http:// to the next field, Twitter common words like “available”, “via”, hashtag topics, Punctuation Marks [19].

2.4 Analysis of Tweets

Different Symbolic and Machine Learning techniques are used to identify the emotions from the text. Machine learning techniques are simpler and more efficient than symbolic techniques. These techniques can be applied for sentiment analysis. There are some issues with identifying sentimental keywords from tweets with multiple keywords. It is also difficult to use misspellings and slang words. To deal with these problems, an effective feature vector is created by performing two-step feature extraction after appropriate preprocessing. In the first step, Twitter-specific features are extracted and added to the feature vector. After that, these features are extracted from the tweets and feature extraction is done again as if it were done on normal text. These features are also added to the feature vector [20].

3 RESULTS

Analyzes are made on the data sets created within the scope of the research, in which the dictionary-based approach is adopted. Aim; classifying tweets as one of the categories of “positive”, “negative”, “anger”, “hate”, “sadness”, “fear”, “expectation”, “joy”, “confidence” and “surprise”. Due to the use of international abbreviations, the majority of tweets are in English. Tweets to be used in sentiment analysis; It was collected by communicating with the Twitter API linked to the

Twitter account. After obtaining authorization from the API, tweets were taken in three separate periods, November 2019, May 2020, and October 2020, for eight institutions determined. 301,586 tweets collected during the study are in raw form. The raw dataset; contains several syntactic features that are not necessary for evaluating the dataset. Such undesirable features need to be pre-processed. For pre-processing, the spaces, URLs, various symbols, and stop words in the tweets have been removed, and capital letters have been converted to lowercase. In this process, which is done to ensure data quality and to make algorithms progress faster and more accurately, the before and after tweets change. As seen in Table 1-3 in the periodical sentiment analysis study of institutions, according to the sentiment analysis results of the datasets taken in November 2019; When institutions are evaluated according to the number of tweets containing positive emotions; IOM, UNDP and FAO are at the top, while UNHCR, UNICEF are at the bottom.

***Table 1**. Distribution of sentiment analysis results of tweets taken btw. November 2019*

	November 2020		
	Positive	**Negative**	**Neutral**
WHO	798	261	5280
UNICEF	285	29	9686
FAO	737	183	9080
ILO	807	307	7548
IOM	937	379	4615
UNDP	812	183	9005
UNHCR	280	196	9524
RC	655	351	8994

According to the results of the sentiment analysis of the datasets taken in May 2020; When institutions are evaluated according to the number of tweets containing positive emotions; UNDP, WHO and RC are at the top, while UNHCR, UNICEF are at the bottom. According to the results of the sentiment analysis of the datasets taken in October 2020; When institutions are evaluated according to the number of tweets containing positive emotions; UNDP, RC and FAO are at the top, while UNHCR, WHO are at the bottom (Table 1,2,3).

***Table 2**. Distribution of sentiment analysis results of tweets taken btw. May 2020.*

	May 2020		
	Positive	**Negative**	**Neutral**
WHO	1533	784	12,499
UNICEF	308	173	16,519
FAO	695	252	9951
ILO	1312	873	14,269
IOM	747	362	4374
UNDP	1563	352	14,190
UNHCR	571	402	16,027
RC	1517	613	14,870

Table 3. *Distribution of sentiment analysis results of tweets taken btw. October 2020.*

	October 2020		
	Positive	**Negative**	**Neutral**
WHO	520	208	16,272
UNICEF	691	307	16,002
FAO	1095	321	13,724
ILO	699	364	12,824
IOM	753	362	4996
UNDP	2764	3761	10,475
UNHCR	860	397	13,555
RC	1850	904	12,205

In the descriptive statistics of the dataset; Institutions with the highest median in November 2019; UNICEF, UNDP and FAO. Institutions with the highest median in May 2020; They are FAO, UNDP and WHO. In October 2020; institutions with the highest medians; UNICEF and FAO (Table 4). During this period, UNICEF's median and average values were remarkably high, while the median of many institutions was quite low.

***Table 4**. Descriptive statistics of tweets taken by institutions btw. November 2019-May 2020 and October 2020*

	November 2019		**May 2020**		**October 2020**	
	Median	**Mean**	**Median**	**Mean**	**Median**	**Mean**
WHO	0.40	0.492	0.40	0.325	0.0	0.304
UNICEF	0.75	0.968	0.00	0.518	1.25	1.171
FAO	0.50	0.533	0.500	0.573	0.50	0.377
ILO	0.25	0.435	0.25	0.324	0.00	0.193
IOM	0.40	0.419	0.25	0.356	0.25	0.233
UNDP	0.50	0.646	0.50	0.555	0.00	0.139
UNHCR	0.00	0.255	0.25	0.048	0.00	0.255
RC	0.40	0.249	0.30	0.309	0.05	0.195

The word clouds containing the most frequently used words of the institutions in tweets on a period basis are presented in Figure 1-8. The most frequently used visualization in tweets analysed in these word clouds.

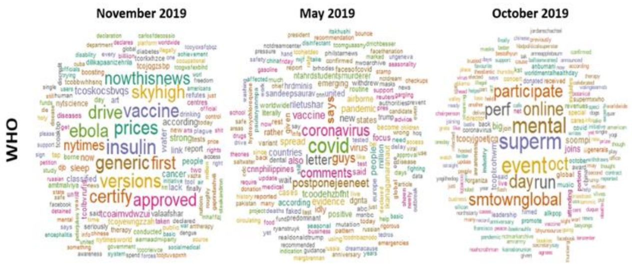

***Figure 1**. Word Clouds of Periodic Datasets of WHO*

***Figure 2**. Word Clouds of Periodic Datasets of UNICEF*

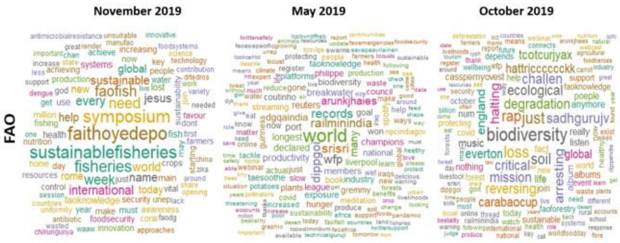

***Figure 3**. Word Clouds of Periodic Datasets of FAO*

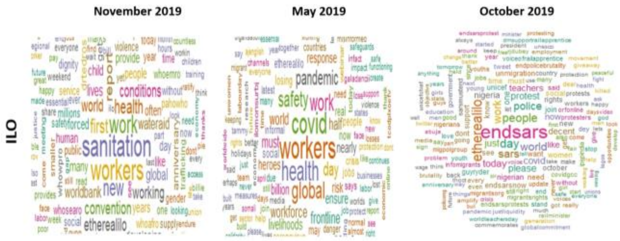

***Figure 4**. Word Clouds of Periodic Datasets of ILO*

***Figure 5**. Word Clouds of Periodic Datasets of IOM*

***Figure 6**. Word Clouds of Periodic Datasets of UNDP*

***Figure 7**. Word Clouds of Periodic Datasets of UNHCR*

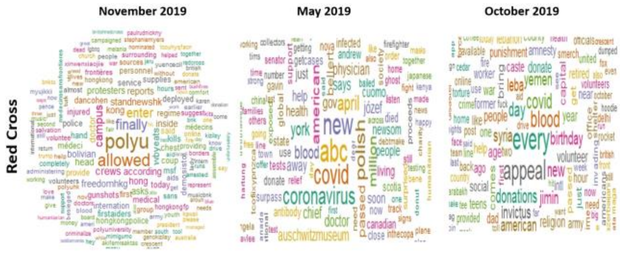

Figure 8. *Word Clouds of Periodic Datasets of Red Cross*

In the sentiment analysis of the tweets taken about the institutions within the scope of the research, "positive", "negative", "trust", "expectation", "joy", "surprise", "hate", "fear", "sadness", "anger" words were used periodically. The averages of their emotions were calculated. In this context; The distributions of the medians of all institutions for a certain emotion for the November 2019, May 2020 and October 2020 periods were tested with the Friedman Test. There was only a significant difference between the emotional medians of the institutions according to the periods of fear ($x2=6.75$; $p=0.034$). When the emotional medians of the three periods of WHO are compared, especially in the beginning of the pandemic, positive emotions (“Expectation”, “Confused”, “Confidence”, “Joy”, “Positive”) decreased, Negative emotions (“Anger”, “Fear”, “Hate”, “Sadness”, “Negative”) increase. In the period of October 2020; emotion medians decrease in all emotions compared to other periods. When the emotional medians of UNICEF's three periods are compared, especially in the beginning of the pandemic, there is a decrease in positive emotions (“expectation”, “surprise”, “trust”, “joy”, “positive”), negative emotions (“anger”, “fear”, “hate”, “sadness”, “negative”). In the period of October 2020; In the emotional medians, there is an increase in all emotions compared to other periods. Comparing the emotional medians of FAO's three periods, especially in the initial period of the pandemic, positive emotions (“expectation”, “surprise”, “trust”, “joy”, “positive”) and negative emotions (“anger”, “fear”, “hate”, “sadness”, “negative”) slight changes are observed. When the emotional averages of the three periods of the ILO are compared, it is observed that all emotions except “positive”, “confidence”, “joy” and “sadness” increase in May 2020 and decrease in October 2020. When the emotional averages of IOM's three periods are compared, a slight increase is observed in the emotions of "negative" and "fear", especially in the initial period of the pandemic. Apart from these increases, there is a periodic decrease in emotional averages in general. When the emotion averages of the three periods of UNDP are compared, it is seen that there is an increase in the average of emotions in general. Especially in the period of October 2020, there is a great increase in Positive emotions and Negative emotions (“Anger”, “Fear”, “Hate”, “Sadness”, “Negative”). When the emotional medians of UNHCR's three periods are compared, an increase is seen in eight other emotions, except for "hate" and "negative" emotions. However; In "hate" and "negative" feelings; The decrease in the period of May 2020 and the increase in the period of October 2020 attract attention. When we look at the emotional medians of the three periods of RC, negative emotions (“Anger”, “Fear”, “Sadness”, “Negative”) correspond to positive emotions (“Expectation”, “Confusion”, “Confidence”, “Joy”, “Positive”) appears to be ahead of it. A large increase is observed in the medians of negative emotions in the period of October 2020 (Figure 9-16).

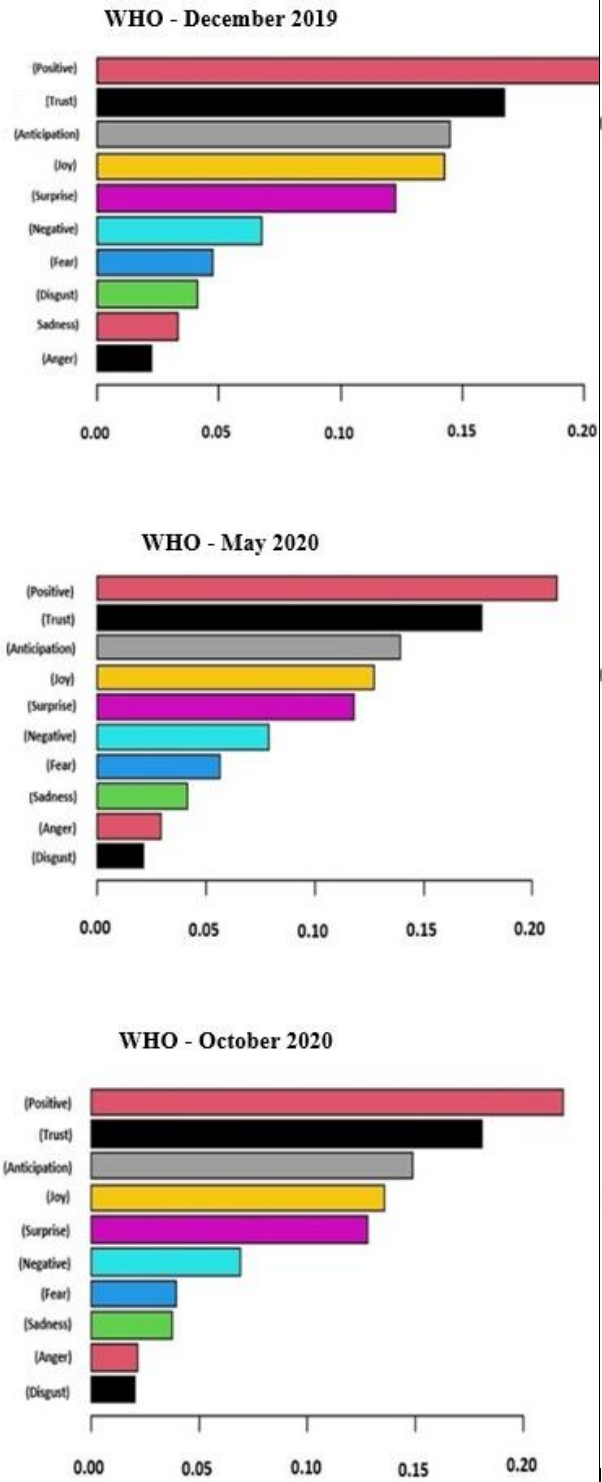

Figure 9. Mood Distribution of Institution's Periodic Datasets of WHO

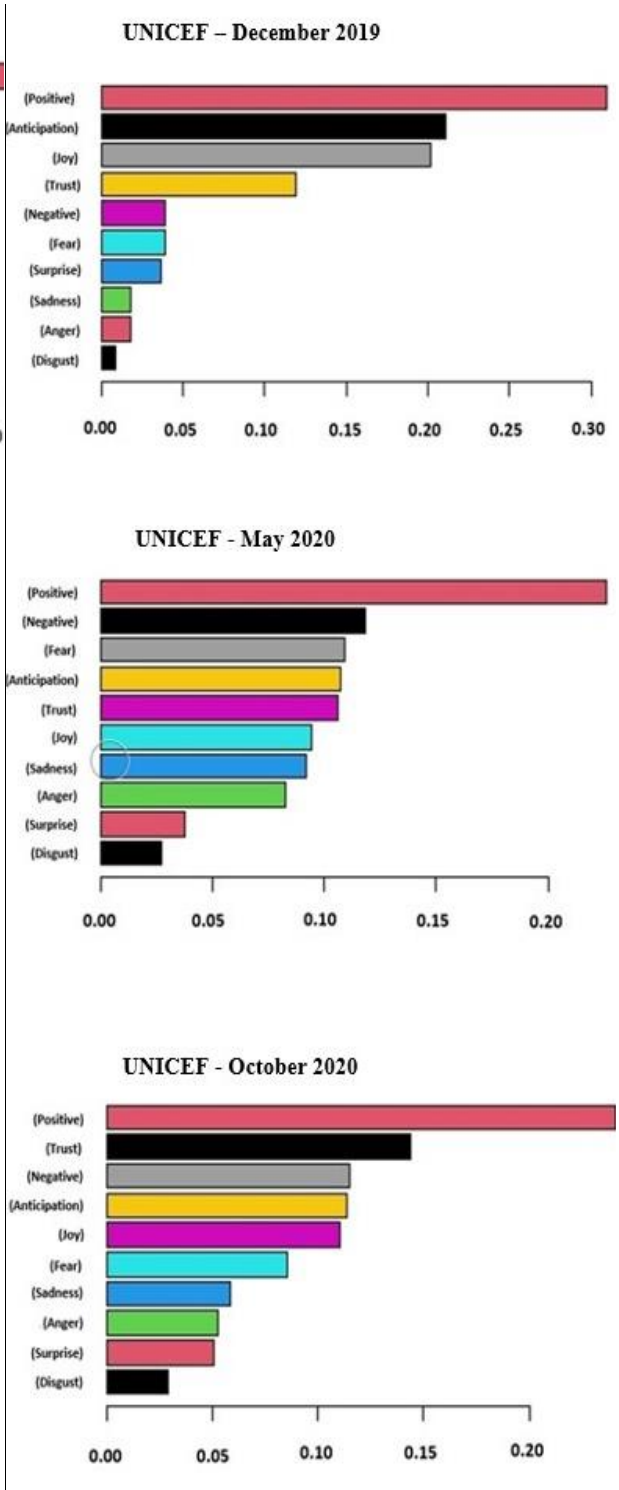

Figure 10. Mood Distribution of Institution's Periodic Datasets of UNICEF

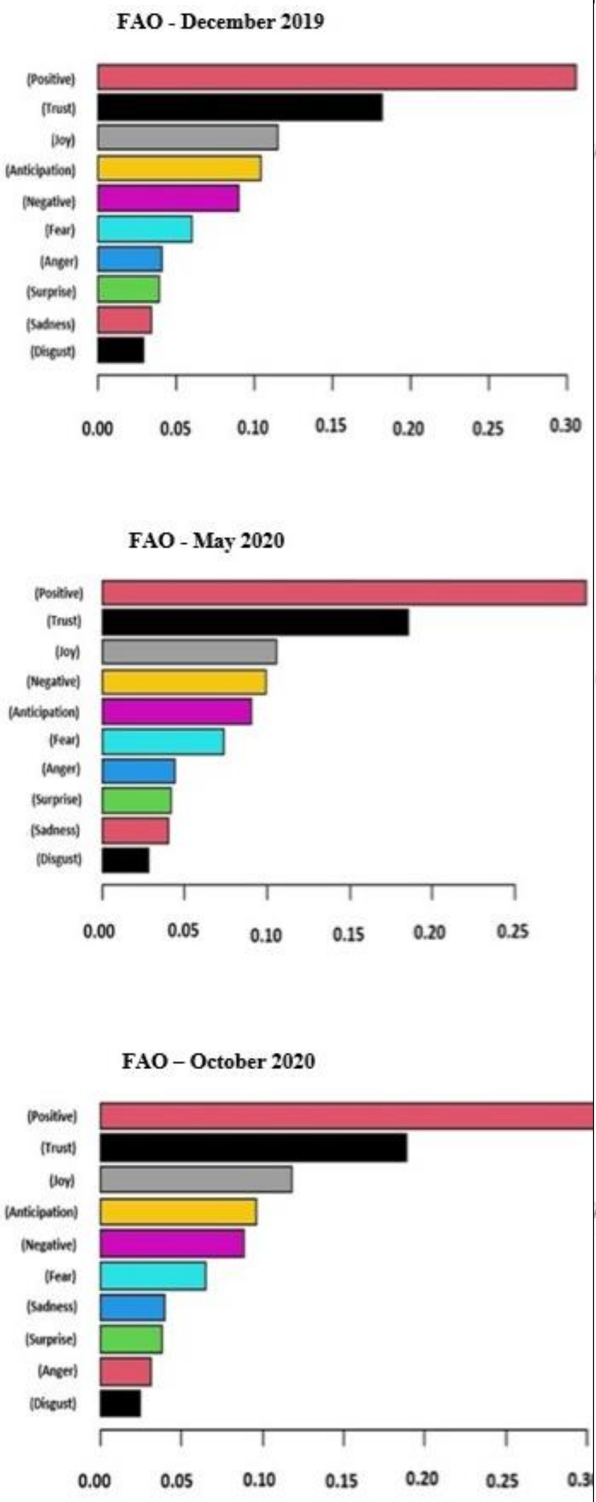

***Figure 11**. Mood Distribution of Institution's Periodic Datasets of FAO*

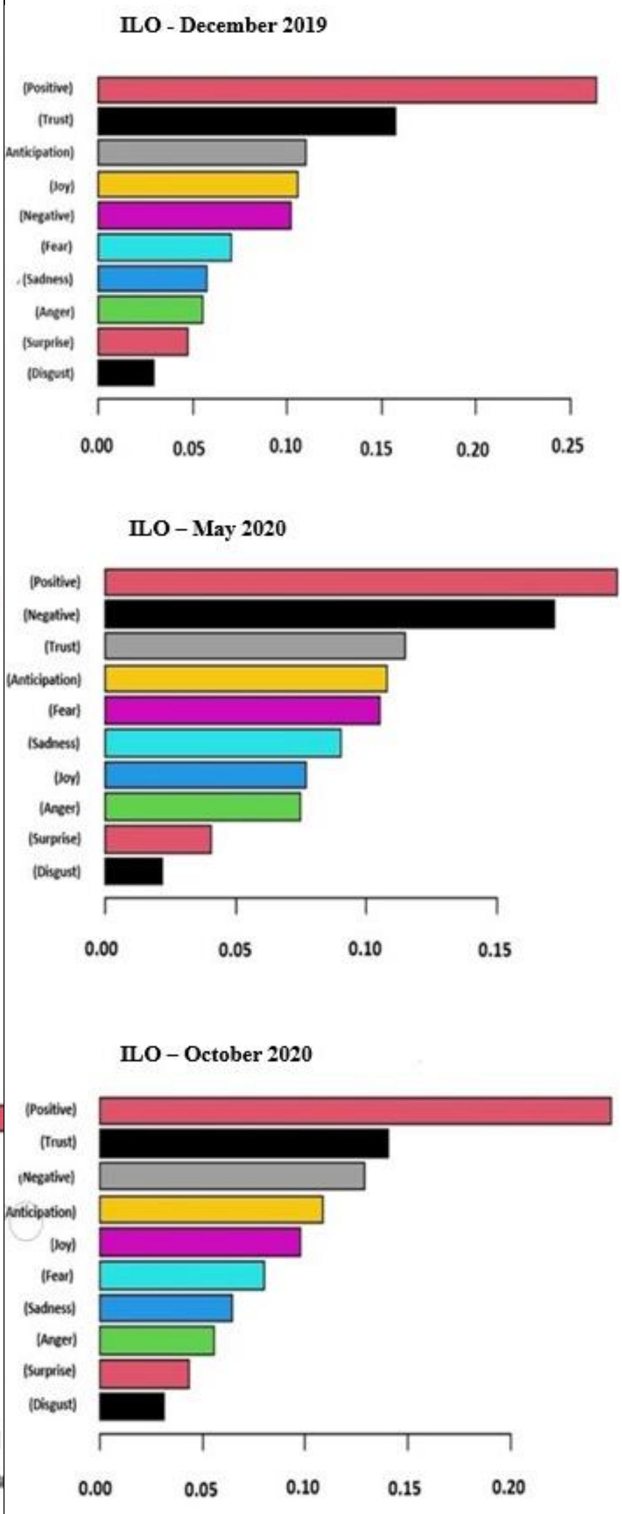

Figure 12. Mood Distribution of Institution's Periodic Datasets of ILO

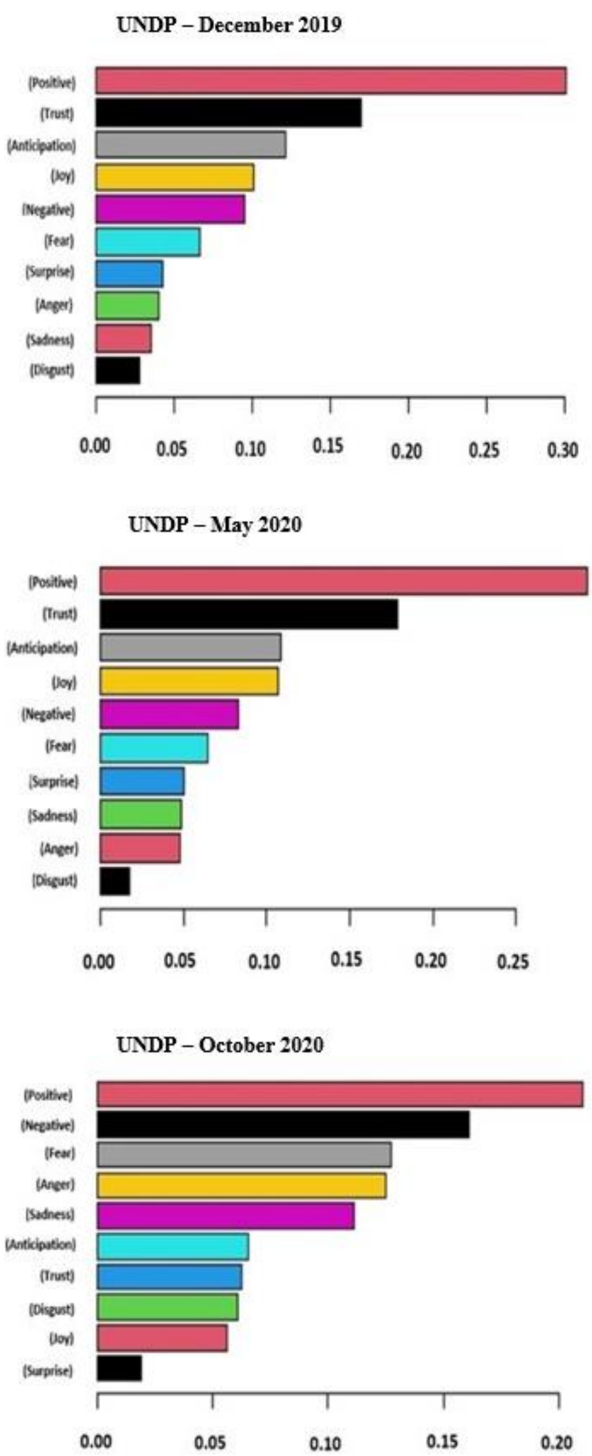

Figure 13. *Mood Distribution of Institution's Periodic Datasets of UNDP*

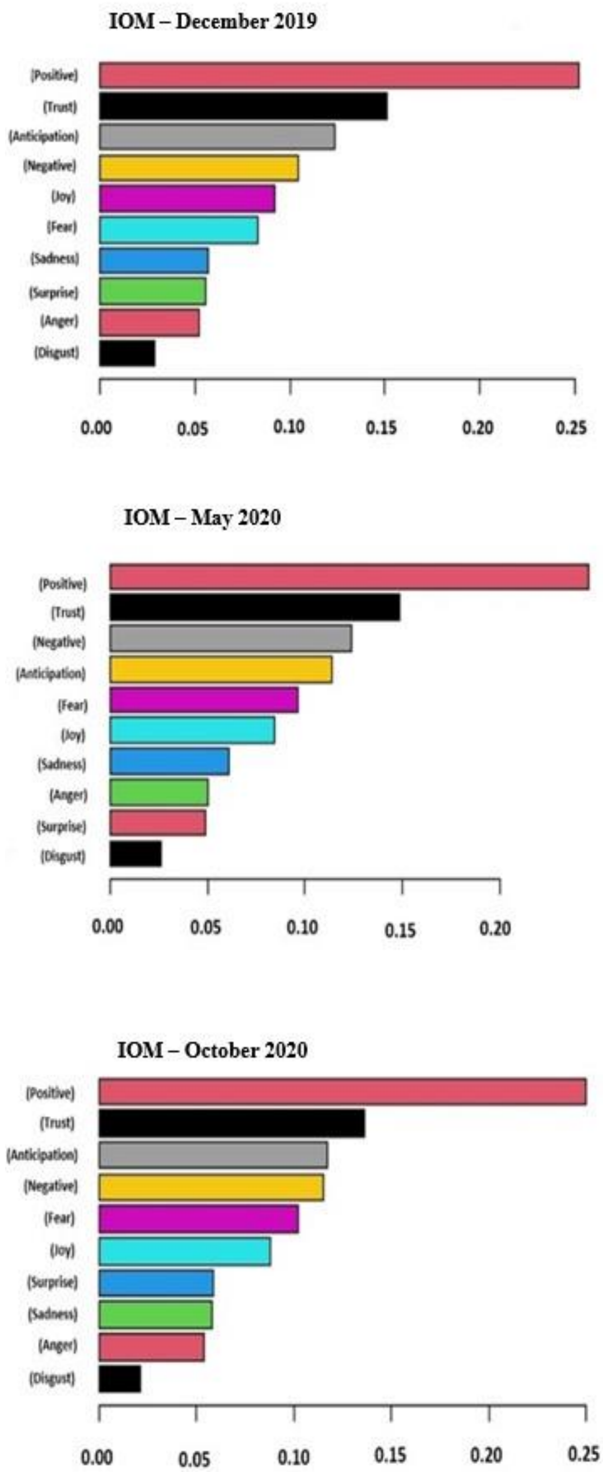

Figure 14. Mood Distribution of Institution's Periodic Datasets of IOM

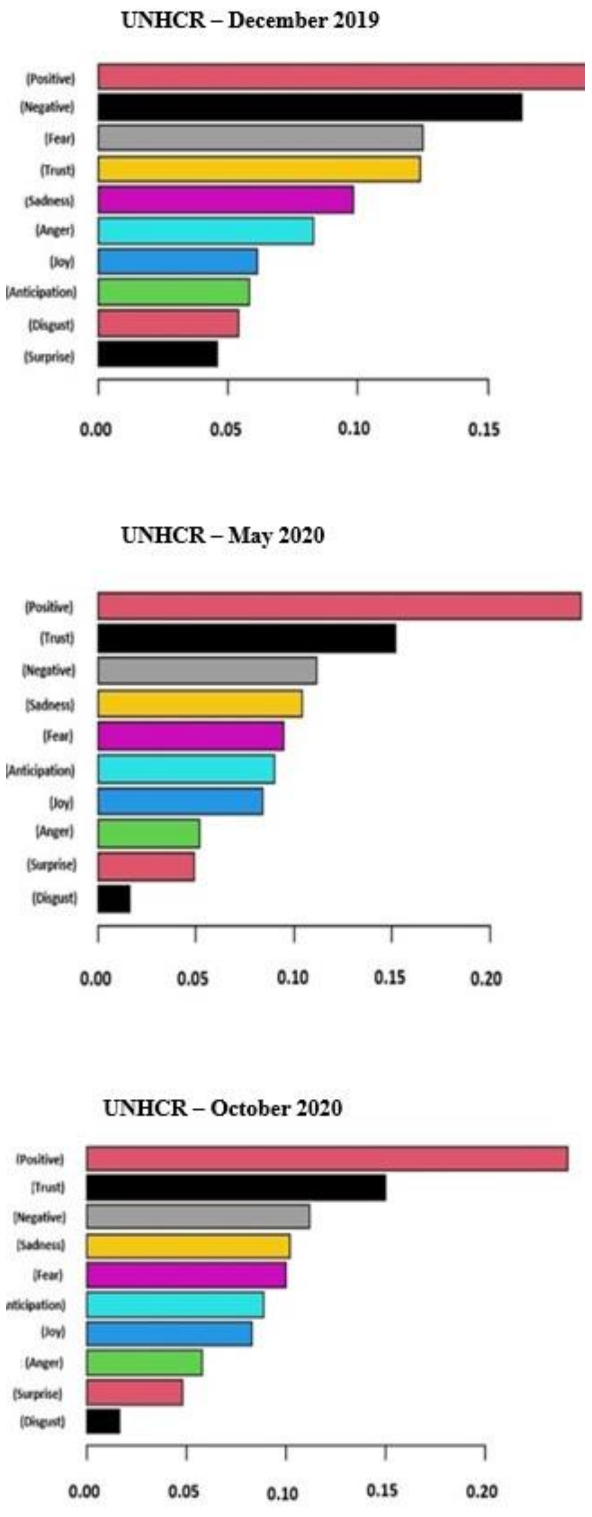

Figure 15. Mood Distribution of Institution's Periodic Datasets of UNHCR

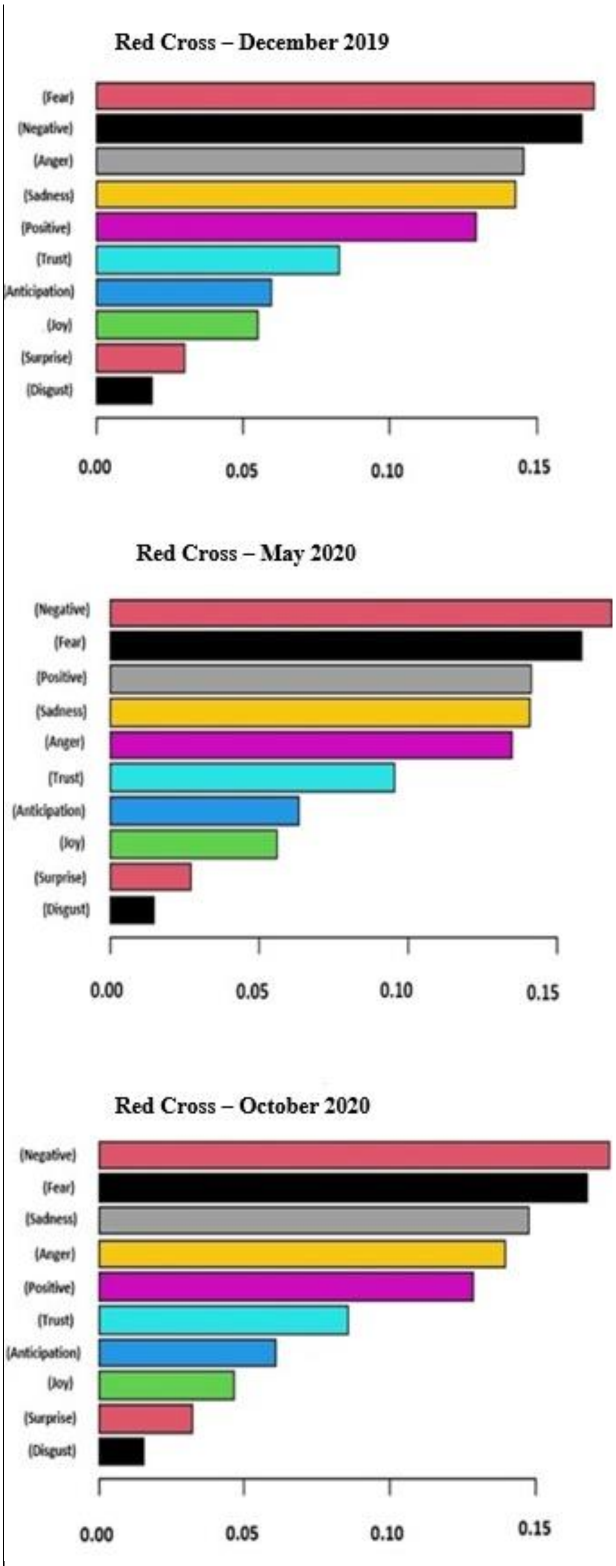

Figure 16. Mood Distribution of Institution's Periodic Datasets of Red Cross

There are differences between the emotional medians of the institutions according to the periods related to Expectation, Trust, Anger, Hated, Surprise, Joy, Sadness, Positive and Negative emotion. The distributions of the emotional medians of the three periods of the institutions in all institutions were tested with the Friedman Test.

Table 5. *Distribution of the emotional medians of the institutions for the three periods in all institutions (Friedman Test)*

	x^2	**P** ($\leq 0,05$)	**Kendall's *W***
Surprised	17,821	0,013	0,849
Expectation	15,333	0,032	0,730
Anger	15,111	0,035	0,720
Sadness	14,556	0,042	0,693
Joy	14,444	0,044	0,688
Negative	14,333	0,046	0,683
Fear	14,222	0,047	0,677
Positive	13,222	0,067	0,630
Trust	13,556	0,060	0,646
Disgust	10,111	0,182	0,481

The distributions of the emotional medians of all institutions for the three periods were tested with the Friedman Test. There is a significant difference between the periodic distributions of Expectation, Anger, Fear, Surprise, Joy, Sadness, Negative emotions and the emotional medians of the relevant institutions. There is no significant difference between the periodic distributions of the three-period medians of Trust, Hate, and Positive emotion across all institutions.

4 DISCUSSION

Researching the direction of the sharing of ideas on Twitter is important in terms of determining the tendencies of people and the emotions contained in the shares. In this context; Sentiment analysis method was used to evaluate tweet texts where WHO, FAO, ILO, IOM, UNICEF, UNDP, UNHCR or RC were tagged or used in sentences. With the NRC emotion dictionary, words are classified according to 10 emotions. Except for the October 2020 period of UNDP, the number of positively tagged tweets was overestimated by negative tweets in all periods of all institutions. In this context, this difference in UNDP can be interpreted as the reflection of poverty and deprivation in developing countries on Twitter. As a result of tagging with the NRC dictionary, the number of neutral tweets was found to be considerably higher than the number of positive and negative tweets. In order to maximize the effectiveness of using Twitter; It is important to understand the factors that will increase the dissemination of information shared by such institutions. There are many studies investigating factors that facilitate the retransmission of tweets, including adding hashtags, URLs, photos, and videos [3], [21]. However; Sentiment analysis of non-profit organizations and their followers' communication on Twitter has not been mentioned much in the literature. The efforts of these organizations to convey their messages to the masses are of high importance for institutions. With these efforts, institutions; He also uses Twitter as his main communication channel, where he publishes mission and various updates and communicates with his followers by adding different content features to his tweets [22].

In the research; As a result of sentiment analysis, the number of retweets containing various factors such as hashtags, URLs, photos and videos in tweets taken in the periods of November 2019, May 2020 and October 2020 was found to be considerably higher than the number of positive and negative tweets in all institutions within the scope of the research. It shows that they are able to realize the dissemination of information, which is one of the main purposes of using social media.

In the study of Park et al.; They examined how major health organizations, such as the sampled American Heart Association, American Cancer Society, and American Diabetes Association, use Twitter to spread health information, build relationships, and promote actions they take to improve health. Content analysis of tweets was conducted to examine these organizations' use of Twitter's interactive features and to understand the message functions and topics of their tweets. As a result, it has been found that all organizations share original tweets most frequently, and the use of retweet and reply functions differs according to organizations. Your followers; It has been revealed that people tend to retweet and like messages [23]. Chung et al., who conducted a sentiment analysis for the Women Who Code, a non-profit organization that supports women's advancement in technology against sexist norms; He noted the use of URLs, adding photos, adding videos, and number of emojis by encoding the content categories for each tweet. In the research findings; It has been shown that using an emoji or URL in a tweet has a positive effect on the retweet. This research of Chung et al.; helping to understand nonprofits' use of Twitter; offers practical implications for tech-savvy female audiences so they can strategically spread their message [22]. In their study, which Thackeray et al. described as the first study to evaluate the public health situation among state health units; He randomly sampled tweets and coded them under the headings of "dissemination of information", "participation" and "action". In the research; It is stated that the units mostly establish one-way communication and focus on personal health. Researchers; states that institutions need to establish more two-way communication and interaction in order to realize their connection and relationship development potential [3]. In this context; Within the scope of the work of non-profit organizations, the research provides followers and supporters with meaningful insights on how mutual exchanges, including periods of great crisis, contain positive emotion and are associated with the retweetability of organizations or factors related to these organizations. However, as the spread of the pandemic increased, this situation caused a change in the feelings and emotions in tweets about institutions. Aydemir and Akyol in their study; they state that hashtag activism against immigrant and anti-immigrant rhetoric resulting from the Covid-19 pandemic has generally received positive reactions and emotions, therefore it has been successful in raising awareness and delivering information to large masses [24]. This work; is in line with the findings of the study. In addition, some researchers; argues that online activists participating in campaigns via social media are less likely to go beyond tweeting [25]. In addition to the findings of sentiment analysis; Statistical analysis of the emotional medians included in the tweets taken periodically on the basis of institutions was made and a significant relationship was found in all institutions except FAO. When the statistical analysis of emotion medians is evaluated; A significant relationship was found between the medians of "fear" feeling of all institutions during the period. With this; in sentiment analysis results; Especially during the pandemic period, there was an increase in the feeling of "fear" in the posts about institutions. In the research of Hubert et al., who investigated state presence and public participation in social media; visual analysis and emotion analysis were used together. Researchers; They stated that they found the effectiveness of Twitter valuable in the fields of health, social development, education, environment and business [26]. Menendez et al.; Sentiment analysis was applied to group the sample of tweets using the #WorldEnvironmentDay hashtag according to the emotions expressed. The tweets, which determine the main factors related to the environment and public health that are most relevant to Twitter users, are grouped according to the Sustainable Development Goals (SDG). Researchers; predicts that research results can facilitate environmental decision making for companies, institutions and non-profit organizations [27].

5 CONCLUSIONS

As a result; health with the Covid-19 pandemic process, which has its own social and political conditions; It has become a global concern for almost all industries. In this context; There is a necessity to evaluate health promotion with a holistic perspective together with technology. This research, in which tweets are classified according to 10 different emotions; non-profit international organizations that make environment, health and sustainable development a principle; It provides a conceptual framework for understanding when and why follower behaviour occurs. This; It is very important for institutions to realize their missions, to create the necessary meaningful support in times of crisis, to increase benefit and awareness, to facilitate decision-making, and to increase communication and interaction. In the research, negation, irony and sarcasm were not included due to the large number of institutions and data collection for 3 periods. This subject, which is the main limitation of the research and which is difficult to analyse in the field of natural language processing and includes different algorithms, is planned to be applied in the future study.

Conflict of Interest

There is no conflict of interest between the authors.

Authors Contributions

The authors' contribution rates in the study are equal. Conceptualization, Ö.Ç. and E.Ö.; methodology, Ö.Ç. and E.Ö.; software, Ö.Ç.; formal analysis, Ö.Ç.; investigation, E.Ö.; resources, Ö.Ç.; data curation, Ö.Ç. and E.Ö.; writing—original draft preparation, Ö.Ç. writing—review and editing, Ö.Ç. and E.Ö.; visualization, Ö.Ç.; supervision, E.Ö.; project administration, Ö.Ç. and E.Ö.

Research and Publication Ethics

The study is complied with research and publication ethics

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AN OVERVIEW OF THE CONVENTIONAL SYNTHESIS OF BIOMASS-DERIVED NANOCOMPOSITES AND APPLICATIONS TO SYSTEMS FOR ENERGY AND THE ENVIRONMENT

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ABSTRACT

Biomass-derived nanocomposites are very tiny carbonated solid materials synthesized by fusing metallic compounds with different types of plant-based materials, either in their raw forms or after processing into other substances such as biochar. This study aims to succinctly describe the principles often applied in the literature for the synthesis of biomass-derived nanocomposites. Furthermore, the most common applications of biomass-derived nanocomposites in the areas of sustainability of energy and the environment are summarized. The roles of bio-nanocomposites in the advancement of energy storage systems, supercapacitors, and hydrogen production through fuel cells are in focus for sustainable energy applications. For the environmental sustainability potential, emphasis is placed on the applications of the bio-based nanocomposites for environmental remediation and carbon-capture purposes by mitigating CO_2 emission through CO_2 sorption and sequestration.

1 INTRODUCTION

Global warming and other associated effects of greenhouse gas emissions have necessitated that drastic measures be taken to promote green processes in almost all sectors of human endeavors [1], [2]. In the energy sector, for instance, this connotes that usage of fossil fuels in energy infrastructures be reduced to the barest minimum [3] and replaced with renewable and clean fuels such as the solar [4], wind [5], biomass [6], hydrogen [7], geothermal [8], and hybrid renewable resources [9]. Adoption of green processes in materials science and engineering implies that the use of natural and renewable materials should be promoted, to reduce environmental wastes and energy use, among others [10], [11]. A very popular and feasible area where green chemistry applies in material science is in the combination of materials to form composites for complementary engineering properties required in some advanced applications [12], [13].

Composites are known technically as the unification of two or more materials with distinct properties to obtain a single material with superior characteristics [14], [15]. If one or more of the components in the unified materials is of nanoscale, the composite so formed is known as nanocomposite [16], [17]. And when a naturally occurring plant, animal waste, or any other form of biomass is included in the synthesis of a nanocomposite, it is generally referred to as biomass-derived nanocomposite or bio-nanocomposite [18], [19], [20].

So many methods have been adopted in the literature to synthesize bio-nanocomposites from different base materials and use diverse biomass types as carbon sources. This chapter aims to succinctly provide an overview of the different methods that have been so adopted to fuse biomass carbon with other materials to obtain bio-nanocomposites and to highlight the different biomass sources that have been explored in this regard.

2 SYNTHESIS OF BIOMASS-DERIVED NANOCOMPOSITES

2.1 Primary Synthesis Principles

Synthesis of biomass-derived nanocomposites involves about 4 general steps: the extraction of carbon materials from the biomass precursor, the preparation of the base metallic material and/or its solution, the formation of form-filling solutions by mixing the biomass carbon with the base material solution, and the production of the desired nanocomposite by an appropriate synthesis method vis-a-vis post-process procedure such as filtering, washing/cooling, and drying. A schematic is shown in Figure 1 to illustrate these basic steps.

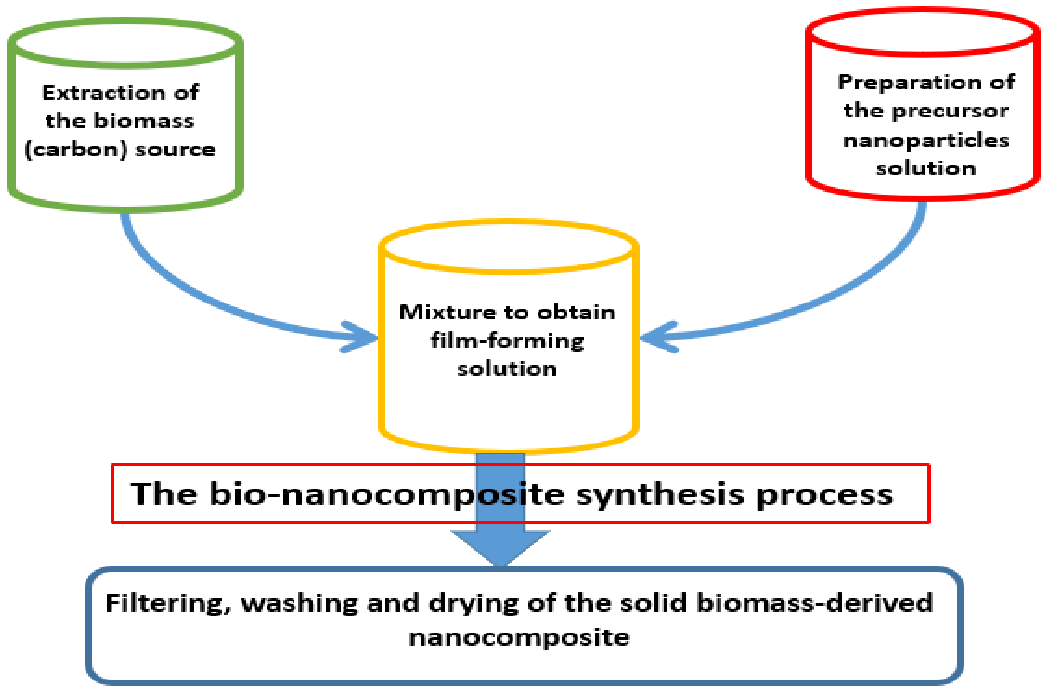

Figure 1*. Basic steps for synthesizing bio-nanocomposites from prepared metallic nanomaterials and extracted biomass carbon*

Emphasis is placed in this chapter on the specific synthesis methods employed for fabricating the bio-nanocomposites from the biomass carbon and the precursor nanomaterial. The following paragraphs report the different conventional synthesis principles that have been used by several authors for the production of nanocomposites from different biomass sources. Additionally, Table 1 highlights the specific biomass sources, the precursor nanomaterial, and the basic synthesis methods adopted in the following paragraphs for the production of biomass-derived nanocomposites.

Wen et al. [21] presented one of such methods to fabricate core-shell carbon-coated CuO nanocomposites using humic acid (HA) as the main source of biomass carbon. Specifically, a synproportionation reaction was employed initially for the production of Cu_2O nanoparticles (NPs) by dissolving $CuCl_2.2H_2O$ in milli-Q water, adding Cu powder, and stirring intensely over a while without any exposure to air, and centrifuging and rinsing with Milli-Q water. Next, the Cu_2O NPs were dispersed in solutions of the humic acid extracted from soil, containing carbon predominantly and oxygen, nitrogen, hydrogen, and sulphur as the other constituent elements. The resulting HA-Cu_2O NPs, after collection through a centrifugation process, purification by rinsing in Milli-Q water, and drying in an oven, were **annealed with argon** at different temperature values to obtain carbon-coated CuO nanocomposites.

Sekar et al. [22] synthesized biomass-activated carbonated tungsten oxide (WO_3/B-AC) using a **sonochemical method**. Bulk WO_3 purchased commercially was first processed into nanoflakes by dissolving in deionized (DI) water, and sonicating the solution, after which the sonicated solution was washed, filtered, and oven-dried. The biomass-activated carbon (B-AC) employed in the study was synthesized from neem leaves. Raw neem leaves separated and washed were sun-dried, and the dried neem leaves, mounted into an alumina crucible, were carbonized in the air to process into ashes. The neem leave ashes were then mixed with potassium hydroxide (KOH) in a mortar and activated in the air at elevated temperature for some time. The potassium compounds that might have been captured in the process were eliminated by stirring the neem leaf ashes/KOH reaction residues in DI water to give proper B-AC nanosheet powder which was then filtered and washed in DI water, and oven-dried. Finally, to synthesize the desired WO_3/B-AC, a quantity of the WO_3 nanoflakes processed above was vigorously stirred in DI water to form a solution, and a portion of the synthesized B-AC nanosheet powder was added to the solution and stirred continuously over a time, and the solution was sonicated over some time, rinsed with DI water, filtered, and dried.

Leite et al. [23] produced biomass-derived nanocomposites by synthesizing gelatin with cellulose nanocrystals (CNCs) obtained from eucalyptus kraft pulp. Specifically, CNCs were prepared from the commercially-obtained eucalyptus kraft pulp by acid hydrolysis. Then, gelatin-CNCs film-forming solutions (FFS) were synthesized by mixing hydrated gelatin powder with CNCs at different concentrations. The desired bio-nanocomposites were produced by the **continuous casting approach** using a KTF-S labcoater casting machine.

Mahardika et al. [24] synthesized bio-nanocomposites using starch extracted from bengkoang tubers based on the method reported in [25] and cellulose nanofibres (CNB) isolated by sonication from pineapple leaf as described in [26]. The desired bio-nanocomposites were synthesized by the **ultrasonication** and drying of the film solutions obtained by mechanical mixing of hydrated bengkoang starch and CNB.

Xu et al. [27] produced bio-nanocomposites by synthesizing chitosan (CS) obtained commercially with nanocrystalline cellulose (NCC) extracted from rice straws. The NCC was extracted from rice straws using acid hydrolysis and ultrasonication procedures [28], [29]. The CS/NCC biocomposites were synthesized by **casting** the film-forming solutions prepared by mixing hydrated CS particles (CS solution) with homogenized NCC suspensions in a polystyrene mold and drying in an oven.

Liou et al. [30] produced a biomass-derived nanocomposite by synthesizing graphene oxide (GO) with silica, which was extracted from rice husk as described in [31]. The desired bio-nanocomposites were obtained by **hydrothermal treatment** of the film-forming solution of GO and the RH-derived silica using a surfactant mixture [32].

Goncalves et al. [33] prepared a carbon/iron nanocomposite by **precipitating** carbonated babassu coconut endocarp in iron nitrate with ammonium hydroxide as the precipitating agent, and by **heat-treating** the ensuing film-forming solutions to obtain the desired bio-nanocomposite.

Zhang et al. [34] synthesized a biomass-derived nanocomposite based on a **facile hydrothermal reaction** that fused MnO_2 with activated carbon derived from silkworm excrement biomass. Specifically, film-forming solutions were derived by the reaction between the calcinated biomass porous material and $KMnO_2$, which were then heated over time, washed, filtered, and dried to obtain the desired MnO_2/carbon nanocomposite.

Gai et al. [35] employed synthesized a nickel-based bio-nanocomposite, a catalyst, using a hydrochar produced from lignocellulosic biomass, pinewood sawdust, as the carbon material infused with the nickel metal precursor. The biomass-derived nanocomposite was fabricated using a newly-developed **one-step hydrothermal reaction**. Specifically, the film-forming solutions, obtained from the dispersed mixture of the biomass hydrochar with nickel nitrate solution, were thermally treated, the slurry formed therefrom filtered and oven-dried, and then calcined under nitrogen gas at high temperature.

***Table 1**. Highlights of biomass sources and synthesis methods for the production of biomass-derived nanocomposites*

Bio-nanocomposite	Metallic nanomaterial precursor	Biomass source(s)	Bio-nanocomposite synthesis method	Reference(s)
Core-shell carbon-coated CuO	CuO	Humic acid	Annealing in an argon gas environment	[21]
Biomass activated carbonated tungsten oxide (WO_3/B-AC)	WO_3	Neem leaves	Sonochemical reaction	[22]
Gelatin-cellulose nanocrystals	Gelatin powder	Eucalyptus	Continuous casting	[23]
Bengkoang-cellulose nanofibres	Cellulose nanofibres	Bengkoang tubers and pineapple leaf	Ultrasonication	[24]
Chitosan-nanocrystalline cellulose	chitosan	Rice straws	Casting	[27]
Silica-graphene oxide	graphene oxide	Rice husk	Hydrothermal treatment	[30]
Carbon-iron	Iron nitrate	Babassu coconut endocarp	Thermal reaction	[33]
Activated carbon-MnO_2	MnO_2	Silkworm excrement	Facile hydrothermal reaction	[34]
Carbon-nickel	Nickel	Pinewood sawdust	One-step hydrothermal reaction	[35]
Carbon-iron	Iron/Chitosan	Rice husk	Solvothermal carbonization coprecipitation	[36]
Protein templated-TiO_2	TiO_2	Expired eggs	Mechano-chemical treatment involving milling	[37]

Siddiqui et al. [36] employed the **solvothermal carbonization coprecipitation** (STCC) approach to synthesize a bio-nanocomposite derived principally from rice husk as the biomass carbon source, chitosan, and iron oxides. The STCC is a single-step approach where the biomass source carbonization process is embedded in the overall synthesis of the nanocomposite. The film-forming solutions were derived by the mixture of ground rice husk with chitosan, $FeCl_3.6H_2O$, and $FeCl_2$ in water and/or ethanol employed as solvents. After the PH modification process using NaOH, the solution was covered with a blanket under a pressurized nitrogen gas condition over time, cooled, filtered, and centrifugated to recover the bio-nanocomposite solid, which was then washed and oven-dried. The authors emphasized the potential of the STCC approach employed in the study to facilitate improved commercial production of biomass-derived nanocomposites relative to the usual facile synthesis methods.

Rodriguez-Padron et al. [37] fabricated a protein-templated TiO_2 (PT-TiO_2) nanocomposite based on a water-free mechanochemical synthesis method. White egg obtained from expired eggs was employed as the carbon source which was mixed with titanium isopropoxide for the film-forming solution, which was then **mechanochemically treated** in a Retsch PM 100 ball mill. Thereafter, the nanocomposite slurry was over-dried and then calcined to obtain the desired PT- TiO_2.

2.2 Microwave-Assisted Bio-Nanocomposites Synthesis

The microwave-assisted method is described as a green synthesis method due to the reduction of the need for solvents and other ancillary substances during the process, and significant reduction of energy usage. It was affirmed in Ming Guo-Ma [38] that the microwave-assisted method has found wide applications in the synthesis of biomass-derived nanocomposites. For instance, cellulose, a biomass material, which can be any of microfibrillated cellulose, microcrystalline cellulose, nanofibrillated cellulose, bacteria cellulose, cellulose nanocrystals, plant fiber, wood fiber, etc [39], has been fused in different forms with other materials to form biomass nanocomposites based on the microwave-assisted method. Some examples of cellulose-based nanocomposites synthesized using the microwave method include cellulose-carbonated hydroxyapatite (CHA) nanocomposite [40], [41], cellulose-F-substituted hydroxyapatite (FHA) nanocomposite [42], cellulose-$CaCO_3$ [43], $CaCO_3$ particles-filled wood powder nanocomposites [44], cellulose-calcium silicate nanocomposite [45], cellulose-Ag nanocomposites [46], cellulose-AgCl and cellulose-AgBr nanocomposites [47], cellulose-CuO nanocomposites [48], etc.

3 APPLICATIONS TO SYSTEMS FOR ENERGY AND THE ENVIRONMENT

Biomass-derived nanocomposites are being explored widely to promote the production of clean and renewable fuels which can both enhance energy security in the future and minimize carbon emissions to the environment. Specifically, biomass-derived nanocomposites, when used as catalysts in the hydrogen production process from biomass wastes, have been reported to enhance both the quality and quantity of hydrogen produced. Rambabu et al. [49] studied the effects of adding iron oxide and date seed activated carbon (Fe_3O_4/DSAC) nanocomposites to the fermentation media for hydrogen production from the dark fermentation of date-palm fruit wastes. The authors reported that the application of the appropriate dosage of the Fe_3O_4/DSAC nanocomposites would increase the yield of hydrogen by about 205% compared to when no nanoparticle is added to the fermentation media. Also, it was obtained that the Fe_3O_4/DSAC nanocomposites would improve the quality of the hydrogen produced by acting as an adsorbent buffer due to the carbon support in the nanocomposites.

The study by Sekar et al. [22] reported that electrodes of the WO_3/B-AC nanocomposites synthesized in the study exhibited superior electrocatalytic features for water splitting in the case of hydrogen production.

Gai et al. [35] reported that the bio-nanocomposite synthesized from nickel metal and pinewood sawdust exhibited highly active catalytic properties that enhanced yields of hydrogen-rich syngas and very low tar yields.

Biomass-derived nanocomposites have also been gaining traction in the literature recently for use in electrochemical energy storage applications, comprising supercapacitors, batteries, and fuel cells [50]. Several biomass-derived nanocomposites have been proven specifically to exhibit very good electrochemical features that afford them competitive advantages over other materials for use as electrode materials in supercapacitors and batteries, few of which are reported in this section.

The carbon-coated CuO nanocomposites fabricated in Wen et al. [21] were reported to possess excellent capacitance and current density values required of electrode materials in supercapacitors and lithium-ion batteries.

The bio-derived carbon synthesized with iron by Goncalves et al. [33] was characterized to possess electrochemical features for energy storage applications in supercapacitors and batteries.

Zhang et al. [34] characterized the MnO_2/carbon nanocomposite obtained with the carbon having silkworm excrement biomass as its precursor. They reported high specific capacitance and outstanding cycling stability for the synthesized MnO_2/carbon nanocomposite, which positioned the nanocomposite as a high-performance energy storage material in supercapacitors.

The PT-TiO_2 biomass-derived nanocomposite synthesized by Rodriguez-Padron [37] was characterized to possess excellent electrochemical properties for energy storage applications in lithium-ion batteries, and outstanding features for use as catalysts.

4 CONCLUSIONS

An overview has been provided in this chapter of different methods for synthesizing very tiny carbonated solid materials, known technically as bio-nanocomposites, by fusing metallic compounds with different types of plant-based materials (biomass). The basic general steps for fabricating bio-nanocomposites have been highlighted, and the applications of such basic steps in the literature for producing different bio-nanocomposites have been summarised. Additionally, microwave-assisted approaches to synthesizing bio-nanocomposites have been succinctly discussed. Moreover, the most common applications of biomass-derived nanocomposites in the areas of sustainability of energy and the environment have been concretized. The roles of bio-nanocomposites in the advancement of energy storage systems, supercapacitors, and hydrogen production through fuel cells are in focus for sustainable energy applications. For the environmental sustainability potential, emphasis is placed on the applications of bio-based nanocomposites for environmental remediation and carbon-capture purposes.

Research and publication ethics

The study is complied with research and publication ethics.

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