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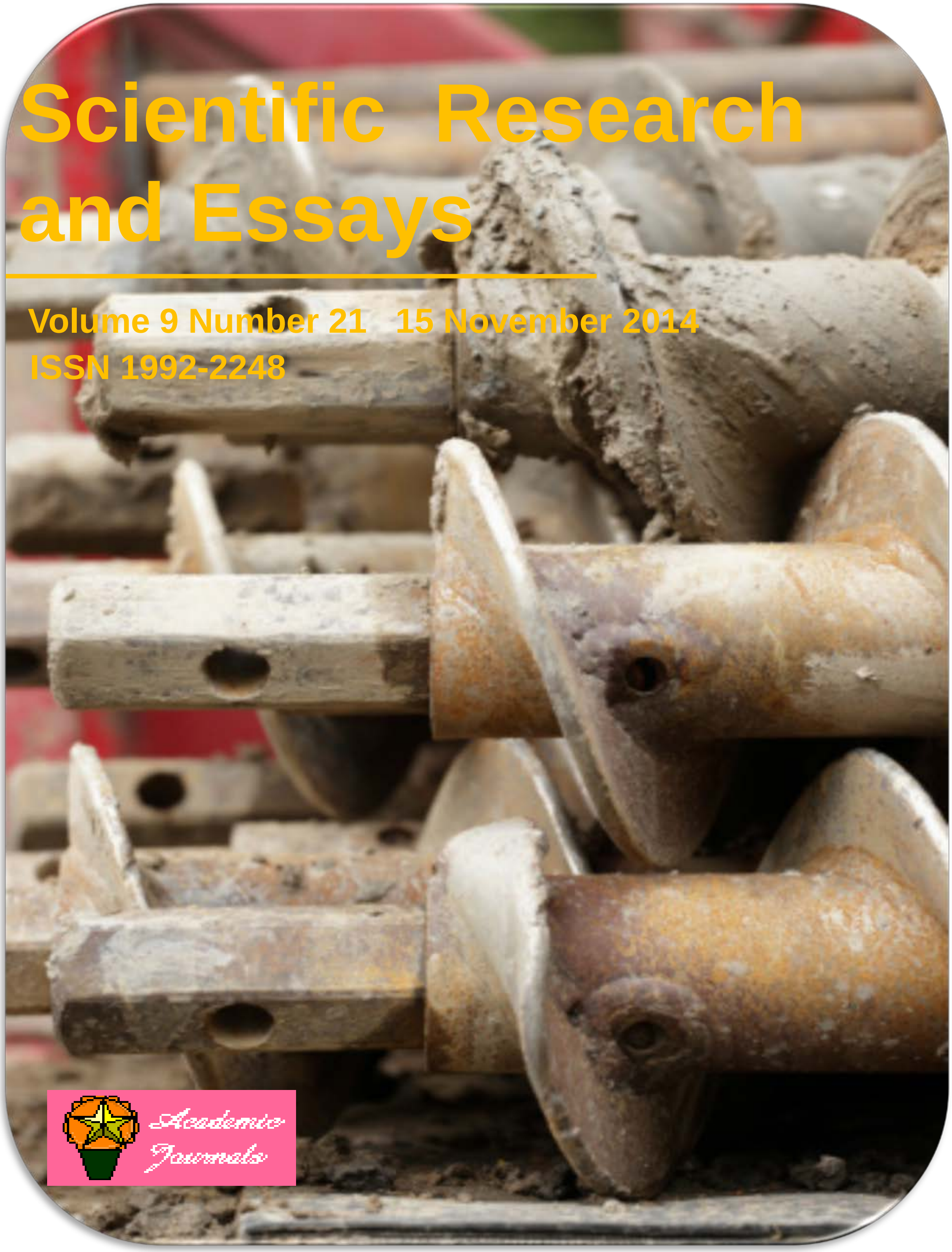

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Scientific Research and Essays

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Scientific Research and Essays

Full Length Research Paper

Effect of industrial tannery effluent on soil fungi and fungal protease/cellulase activity on modified rice husk /modified sawdust medium (MRHM/MSDM)

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The release of unprecedented tannery effluents into agricultural fields constitutes danger to land fill and nutrient cycling as well as organic matter processing. In the present study, tannery effluent discharged soil (polluted landfill), undischarged soil (control) and effluent discharged (waste) were collected from the surrounding areas of tannery industry. The physico-chemical and biological properties and soil protease / cellulose were examined. The study shows that the value obtained from the colour, odour, pH, electrical conductivity and water holding capacity of the polluted soil was black, foul odour, 5.12, 0.72 µMhos cm^{-1} and 0.51 mg/l, respectively. In chemical parameters, organic matter, total nitrogen phosphorus and potassium have the following values: 8.2, 1.2, 0.15 and 0.39% respectively. In all ramifications, the polluted soils showed higher values than the control except that of potassium. The soil protease/ cellulose activities of the selected fungal were observed on different media (modified rice husk, modified saw dust and on control liquid media respectively). The activities were found to be higher on MRHM and MSDM (2.81 and 1.82 IU/ml) at maximum of 45 days than the control liquid media (1.23 IU/ml) at maximum of 15 days; they decreased to 0.312 IU/ml at 30 days. It was found that *Rhizopus nigricans* exhibited the highest cellulase activity (2.81 IU/ml) followed by *Aspergillus niger* (1.82 IU/ml) and the least *Penicillium* species (0.98 UI/ml) respectively.

Key words: Protease/Cellulase, *Rhizopus*, *Aspergillus, Penicillium* solid state/submerge fermentation, tannery waste and contaminated soil.

INTRODUCTION

Soil is an important system of terrestrial ecosystem. There is a direct impact of pollutants ion minerals, organic matter and microbial community of soil (Nagaraju et al., 2007). The discharge of industrial effluent especially

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without treatment may have profound influence on the physico-chemical and biological properties of soils, in relation to soil fertility. A wealth of information on occurrence of changes in properties of soils due to discharge of effluent from other industries is available such as cotton ginning mill (Narasimba et al.,1999), sugar industry (Nagaraju et al., 2007), dairy waste water (David, 2010) and dairy industry (Nizamuddin et al., 2008). Effluents from leather processing, a major industry that produces huge volume of waste water normally discharged to irrigate agricultural lands. This tannery waste water contains a very little amount of proteins except for the sludge waste that has nitrogenous compound from hide and skin of animals. Tannery effluent in the settling reservoir is usually drained to another temporary reservoir, leaving the sludge in the main reservoir for a while, which later becomes a solid waste. The effluent in the temporary reservoir is later released with contaminants into the land fill such as salts and chromium that might affect soil process and crop production (Alvarez-Bernal et al., 2006). During leather processing, the following steps are taken into cognizance: the chemicals use *viz,* lime, sodium sulphate, salt and solvents, which are quite toxic. Thus, they remain one of the worst offenders of the environment (Kamini et al., 2010).

Parkia biglobosa can be found in a belt stretching from Atlantic coast in Senegal to Southern Sudan and Northern Uganda (Thiombiano et al., 2012). The tree currently exists within a wide range of natural communities but is most abundant in anthropic communities where cultivation is semi-permanent (Janick, 2008). Annual production of seeds in Northern Nigeria is estimated at around 200,000t, while the products of the trees are not common in international trade (Ntui et al., 2012).

Yellow-purple or yellow pericarp which contains the seeds is naturally” sweet” and is processed into a valuable carbohydrate food known as “Sikomu and dodawa” among the Yoruba and Hausa people of Nigeria respectively (Olaniji, 2013). The yellow pericarp which is known as waste from *P. biglobosa* is naturally and highly rich in glucose (69%), while the most valuable parts of the locust bean are the seeds themselves which are high in lipid (29%), protein (35%) and carbohydrate (16%) and are good source of fat and calcium for rural dwellers (Gbolagunte et al., 2003; Ntui et al., 2012).

Fermentation processes may be divided into two systems: submerged fermentation (SmF), which is based on microorganisms’ cultivation in a liquid medium containing nutrients, and solid state fermentation (SSF), which consists of microbial growth and product formation on solid particles in the absence (or near absence) of water; however, substrate contains sufficient moisture to allow microorganisms’ growth and metabolism (Pandey et al., 2008). In recent years, SSF has received more interest from researchers since several studies have demonstrated that this process may lead to higher yields and productivities or better product characteristics than SmF. In addition, due to the utilization of low cost agricultural and agro-industrial residues as substrates, capital and operating costs are lower compared to SmF. The low water volume in SSF has also a large impact on the economy of the process mainly due to smaller fermenter-size, reduced downstream processing, reduced stirring and lower sterilization costs (Pandey et al., 2008).

Fungi and bacteria are the main natural agents that degrade cellulose and their population includes aerobic and anaerobic mesophilic bacteria, filamentous fungi, thermophilic and alkaliphilic bacteria, actinomycetes and certain protozoa (Lederberg, 1992). However, fungi are well known agents that decompose organic matter, in general and cellulosic substrate, in particular (Lynd et al., 2002). Cellulase producing fungi include genera *Trichoderma, Penicillium, Botrytis Neurospora, Aspergillus niger, Aspergillus terreus, Rhizopus stolonifer* and *Aspergilli* (Pothiraj et al., 2006). Fungi are capable of decomposing cellulose, hemicelluloses and lignin in plants by secreting enzymes (Abd-Elzaher and Fadel, 2010).

A variety of microorganisms such as bacteria, fungi, yeast and *Actinomycetes* are known to produce these enzymes (Madan et al., 2002). *Aspergillus*, *Penicillium* and *Rhizopus* are especially useful for producing proteases, as several species of these genera are generally regarded as safe (Madan et al., 2002). *Aspergillus ciavatus* ESI has been recently identified as a producer of extracellular belching stable alkaline protease (Haiji et al., 2008).

Cellulase is an important extracellular microbial enzyme, which hydrolyzes cellulose. It is also one of the cheapest sources of biomass utilized for pressing in the fruit juice industry and other factories via enzyme bioconversion, which proves to have a high industrial value. A great number of microorganisms, mostly fungi are able to degrade cellulose for their growth and produce a complete set of cellulose for the hydrolysis of cellulose to soluble sugar (Nigam, 2009).

Microbial enzyme has been severally used on various waste materials. However, prohibitive cost limits their extensive utilization especially in developing countries. Because of growing interest, the low cost is easily available and environment friendly. Agricultural residues have been tested as biodegrading recipes by microorganisms as well as metal biosorbent and a number of agro-based plan waste materials such as papaya wood (Saeed et al., 2005) and rice husk (Tarley and Arruda, 2004). Coconut fibres (Espinola et al., 1999) and black grain husk (Saeed and Igbal, 2003) have been reported as potential degrading recipe by fungi as well as biosorbents for chromium ion removal.

Soil and microbial enzymes occupy a vital role in catalyzing reactions associated with organic matter decomposition and nutrient cycling (Sinsabaugh, 1994). Protaeses participating in the protein catabolism either by degradative or biosynthetic path ways release hormones and pharmacologically active peptides from precursor proteins (Vivian et al., 2008). Proteases are actively involved in carbon recycling and biological transformations of soils fertility (Bolon et al., 2008).

The main objective of this study is to investigate the impact of effluents of leather industry on soil physical properties, biological properties and fungal protease/cellulase activities on the feasibility of rice husk, sawdust in conjunction with conventional media in order to establish an economically viable method for microbial degradation of different substrates by solid state/ submerge fermentation respectively. The abundance of rice husk, sawdust and yellow- purple pericarp in most developing countries as well as its composition and cost effectiveness make them a strong candidate to be used as recipe for removal of many pollutants from aqueous solution using fungi.

MATERIALS AND METHODS

Collection of soil samples with/without effluent discharge

Soil samples with effluent discharge were collected from Mario Jose tannery located at Challawa Industrial Estate, Kano State. Sample without effluent discharge that served as control was collected from adjacent site 3 km away from the leather industry. Soil samples both with and without effluents were used for the determination of physical, biological and fungal properties with respect to their protease/cellulase activities on solid state /submerge medium.

Collection of effluent sample discharge

Effluent samples discharge were collected just 100 m away from Mario Jose tannery. The sample bottles with the caps on were sterilized by autoclaving at a temperature of 121°C for 15 min. These sterilized sample bottles remained capped until the effluent samples were collected at each site. The collected samples were transferred to the laboratory as quickly as possible and kept in the refrigerator in readiness for enumeration of fungal by serial dilution methods after growth on PDA media.

Collection of bio-waste subtrates

Rice husk, sawdust and yellow pericarp from (*P. biglobosa)* were collected from Samaru, Zaria and Sarkin Power, Kaduna and Niger States of Nigeria, respectively.

Physico-chemical properties of the polluted and control land fill were determined in accordance with standard analytical methods (APHA, 2000).

Isolation and identification of fungi from soils and effluent samples

Micro flora such as fungi populations of both soil and effluent samples were enumerated by serial dilution technique. 10 g and 10 ml of each soil and effluent sample respectively were serially diluted and 0.1 ml was gradually spread with a spreader on potato dextrose agar medium for the growth of fungi. Smear of the isolated fungi was prepared in lactophenol cotton blue method. Cultural characteristic such as colure, size of colonies of fungal isolates, size and shape of conidiophores/ fruiting bodies and conidia were measured and recorded. Fungal isolates were identified by matching these characteristics with that of Adawiah (2008).

Cellulase activity determination

The cellulose activity was determined by streaking the identified fungal cultures individually on the carboxy methyl cellulose agar plate and was incubated at 30°C. After 5 days of growth, the zone was identified around the culture by treating the plate with Congo red and NaOH**.**

Inoculum preparation by selected tolerance fungi

Selected tolerance fungi *viz, A. niger, Rhizopus nigrican and Penicillium* sp were maintained by stock culture in PDA agar slants. They were grown at 37°C for 24 h and stored at 4°C for regular sub culturing. 100 ml of inoculums was prepared for each culture using prepared PDA from Irish potato in 250-ml flask. The inoculum was kept in shaker (200 rpm) at 37°C for 24 h in readiness for fermentation processes.

Treatment of agricultural waste (rice husk and sawdust)

Agricultural waste either rice husk or sawdust was procured from Sabon Gari market, Zaria and brought to the laboratory for analysis. The waste was grinded and sieved to obtain a fine texture. Two hundred and fifty grams (250 g) of fine texture was washed and added to 1000 ml of basal media with the following composition (g/L); NH_4SO_4 - 1.0; K_2HPO_4 - 1.0; $MgSO_4.7H_2O$ - 1.0; $CaCO_3$ - 4.0 and $NaNO_3$. They were then mixed and boiled to semi solid slurry after which a prepared solution of 250 g of yellow *P. biglobosa* (Dorowa) was added and boiled to breakdown the complex organic compound to simpler substance as carbon sources. The paste slurry was later spread on a dried sterile tray and oven dried at 40°C for 7 days. The pH of the paste slurry was brought down using *Tamarinda Indica* (Tsamia) from 3.5 to 4.5 and was dried as cake for further analysis.

Biodegradation studies using selected fungal culture for production of protease/cellulase

The degradable capabilities of the three fungi species were selected after testing for their tolerance to Cr SO_4 solution at 4% concentration in the laboratory, while the less tolerance organisms died at 1% concentration (Gbolagunte et al*.,* 2003). Single and combination of these tolerable fungi were studies in modified culture medium *viz, A. niger, R. nigricans* and *Penicilium*

Table 1. Physicochemical properties of contaminated and control land fill of leather industrial area.

Properties	Contaminated soil	Control soil
Colour	Black	Brown
Odour	Foul	Normal
pH	5.12	6.90
Electric conductivity µ (Mhoscm^{-3})	0.72	1.27
Water holding capacity (M/g^{+1}) of soil	0.51	0.3
(Texture)		
Sand(g)	56	73
Silt(g)	24	21
Clay(g)	16	8
Organic matter (%)	8.2	4.32
Total nitrogen (%)	1.21	0.15
Phosphorus (%)	0.15	0.01
Potassium (%)	0.39	1.04

sp of all the three fungi. Twenty gram of the modified rice husk medium was added to different volumes (50, 65, 75, 85 and 100 ml) of distilled water in 250-ml conical flask. The pH was adjusted to 5.2 and sterilized in an autoclave at 121°C for 15 min. The solution was allowed to cool. The inoculum of fungi cell suspension was prepared by adding 5 ml of sterile distilled water to freshly grown fungal mycelia in slant agar bottle. 4 ml of spore suspension containing *A. niger* was then inoculated into the conical flask containing sterile MRHM and deionized water. The conical flasks were incubated for 0, 15, 30 and 45 days at 32°C. This procedure was carried out using potato dextrose medium (PDM) as the growth substrate on *R. nigricans* and *Penicillium* sp as inoculants. All the samples were filtered at specific interval using dampened cheese cloth and were centrifuged at 600 rpm for 15 min. The clear supernatant was used as a source of extracellular enzyme**.**

Protease assay

Protease activity was determined according to the modified Anson's method. 1.0 ml of the culture broth was taken in a 100 ml flask and 1.0 ml of pH 7.0 phosphate buffer added to it. 1 ml of the substrate (2% Hammersten's casein pH 7.0) was added to buffer enzyme solution and incubated at 37°C for 10 min in a water bath. At the end of 10 min, 10.0 ml of 5NTCA (trichloroaceticacid) was added to stop the reaction. The precipitated casein was then filtered off and 5.0 ml of the filtrate was taken in a test tube. To this, 10.0 ml of 0.5 N NaOH solution and then 3.0 ml of the folin ciocalteu reagent (one ml diluted with 2 ml of distilled water) were added. Final readings were taken in a spectrophotometer at 750 nm. Blanks of the samples were prepared by adding the TCA before the substrate. The effect of various factors like inoculums size, carbon source, nitrogen sources, pH and temperature on the production of protease was studied.

RESULTS AND DISCUSSION

Physico-chemical properties of contaminated and control land fill like those of pH in Table 1, showed considerable increased from 5.12 to 6.90. Soil texture in terms of gram of sand, silt and clay was 56, 24, and 16 in the contaminated soils and 73, 21, 8 in the control soil, respectively. Higher water holding capacity was observed in contaminated soil than control; values were found to be 0.53 and 0.3 mg/l respectively. The electrical conductivity of both contaminated and control soil was 0.72 and 1.24 µMhos cm^{-1} respectively. Increased water holding capacity and decreased electrical conductivity in contaminated soil may be due to the accumulation of organic wastes such as amino acid residues and alkalis in tannery industries (Alvare-Bernal et al., 2006). The parameters like organic matter, total nitrogen, phosphorus and potassium all in percentage were higher in all ramifications from contaminated land fill than the control soil except potassium content. The values of above properties of contaminated soil sample were 8.2, 1.21, 0.15 and 0.39% and that of the control soil were 4.32, 0.15,0.01 and 1.04% respectively. The microbial populations of soil samples and tannery effluent discharges are shown in Tables 2, 3 and 4. The fungal populations were relatively higher in control land fill by about 2 times than those of tannery waste polluted landfill and tannery waste effluent. The control soil sample contains the fungal population with 20.0 x 10^3 colony forming units (CFU/g) of the soil recorded in respect to soil with effluent discharges as against the tannery waste polluted landfill. The fungal population had 20.0 x 10^3 CFU/g being the highest from control soil followed by tannery waste polluted landfill of 9.7 x 10^3 CFU/g; the least recorded was 4.8 x 10^3 CFU/ml by effluent waste.

The morphological and microscopic characteristics of

Table 2. Microbial population in control soil.

Isolate Code	Macroscopic characteristics			Microscopic characteristics				Probable organism
	Colour of special hyphae	Colour of subtrate hyphae	Shape of hyphae	Nature of hyphae	Presence of special structure	Appearance of Sporangiophore	Characteristics of spire head	
B01	Black	Brown	Oval	Non – septate	Round columns present	Long erect non-separate	Multinucleated vesicle	*Aspergillus niger*
B02	Brown	Black	Globose	Long non septate	Rhizoid stolon columnal	Long sporran guim	Large and round at the Apex	*Rhizopus nigricans*
B03	Whitish yellow	Brownish green	Oval	Septate	Foot cell giving rice to conidiophores	Long erect non separate conidiophores	Vesicles small into multinucleated	*Aspergillus flavus*
B04	Grayish green	Grayish blue	Globose	Septate	Foot cell present	Long erect non separate conidiophores	Radiating sterigma	*Aspergillus fumigates*
B05	Microscopic present pseudomy chamy clono arthrosphire	Blasphire celium pure present	-	Septate	No foot cell	Microscopic white Cream	Microscopic white to Cream	*Candida* sp
B06	Green/blue greenish	Greenish	Globose	Septate	Foot cell give rise to conidiophores	Erect and non separate conidiophores	Finger-like sterigma	*Penicillum* sp
B07	Green/blue green	Greenish	Globose	Septate	Foot cell giving rise to conidiophores	Short erect non separate conidiophore broom like	Brown like sterigma	*Penicillium* sp
B08	Upper white to permanent light brownish under amber	Light brown under amber	No conidiosphore	Septate	Foot cell present	Non present	Roundish oval pear shape	*Trichophyton schoenleinii*
C01	Gray white	PMX Varieties	Globose	Septate	Foot cell not seen	Short erect non-separate conidiosphore	Multinucleated conidia	*Cephalosporium* sp
C02	Cotton white	White and gray	-	Septate with dichotomous	Initially yeast like then metamophosis into mycellum	Separate arthrospore	White	*Geotrichum* sp
C03	Wooly greenish colour	Velvety	-	Septate	No foot cell	Separation of nitrosphine within the cell wall	Elongated rounded thin wall at the end	*Coccidiodes immitis*
C04	White to brownish with reverse	Brown reverse	Oval short conspicuous Centro mere	Septate	Foot cell not seen	Conidiosphore are short or oval	Round oval conidia	*Paraccocidiodes Brasilensis*

(TOTAL CFU/g): $20.0x10^3$.

fungal cultures isolated from soil samples with/without tannery industry effluents are listed in Table 2 on the basis of a comparison of these characteristics with those recorded by Adawiah (2008). Twelve isolates identified *viz, A. niger*, *Aspergillus flavus*, *R. nigricans*, *Aspergillus fumigatus*, *Candida* sp, *Geotrichum* sp, *Penicillium notatum*, *Penicillium expansium*, *Coccidiodes immitis, Trichophyton schoenleinii, Paraccocidiodes bransilensis* and *Cephalosporum* sp from the control land fill. The former two samples of tannery waste polluted landfill and tannery effluent waste had five each as seen in Table 2, Plate 2 and Plate 3 except in Plate 1 that shows only the pollutants in polluted lands respectively. The dry modified rice husk medium recipe and the growth of *Rhizopus nigrican* from tannery effluent/chrome buffing dust tolerance species are shown in Plate 4 and 5 both are significantly presented in readiness for biosorption studies in-situ. Abundance and activities of micro flora in soil strata are controlled by the availability of water, nutrient, pH, concentration of metal ions, and hydrodynamic communication with the ground

Table 3. Microbial population in tannery wastes dumpsite (polluted landfill).

Organisms	Colony forming unit (CFU/g)
Aspergillus niger	3.0 x 10^3
Rhizopus nigricans	1.20 x 10^3
Aspergillus flavus	2.0 x 10^3
Aspergillus fumigatus	2.20 x 10^3
Penicillium sp	1.30 x 10^3

(TOTALCFU/g)= 9.7 x 10^3.

Table 4. Microbial population in tannery wastes effluent.

Organisms	Colony forming unit (CFU/ml)
Aspergillus niger	1.20 x 10^3
Rhizopus nigricans	1.0 x 10^3
Aspergillus flavus	1.2 x 10^3
Aspergillus fumigatus	1.4 x 10^3

(TOTAL CFU/ml)=4.8 x 10^3.

Plate 1. Dumpsite for chromium sulphate salts and chrome buffing dust (CBD).

Plate 2. Mixed culture of fungi isolated from control landfill.

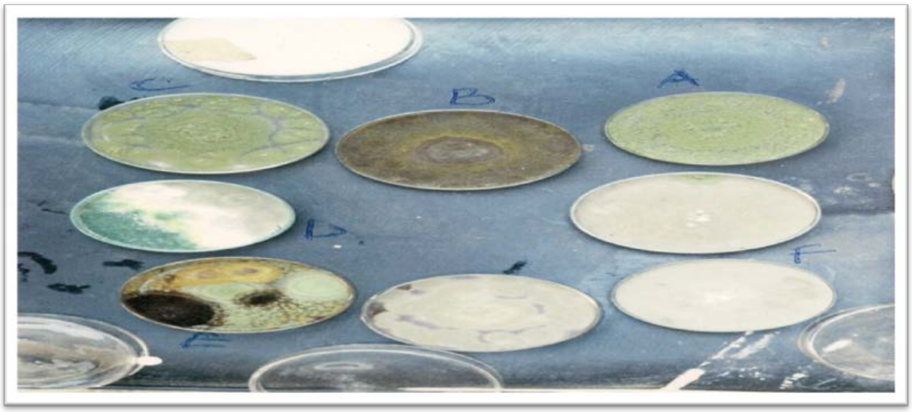


Plate 3. Mixed culture from tannery effluents /chrome buffing dust. A-*Aspergillus fumigatus,* B-Old culture of *Aspergillus niger,* C-*Aspergillus fumigatus,* D-*Penicillium* sp, E-*Aspergillus flavus*, *Aspergillus niger*, *Aspergillus fumigates*.

Plate 4. Dry modified rice husk medium.

Plate 5. *Rhizopus nigricans* from tannery effluents /chrome buffing dust.

Table 5. Protease/cellulose activity of fungi isolates as indicated by their relative clearance zone after their tolerance level of $CrOSO_4$ at 4% concentration were tested.

Name of the organisms	Zone of clearance
Aspergillus niger	++++ (Abundance growth)
Rhizopus nigricans	+++ (Moderate growth)
Penicillium sp	+++ (Moderate growth)

surface and so on. Environmental stresses brought about by the contamination could be a reason for the reduction in microbial species but increasing the population of few serving species. The soil samples collected from polluted sites were mostly affected by waste water irrigation due to the presence of heavy metal which affects the population densities of fungi. The differences between the sampled sites regarding their richness on microbial isolates appear to be closely linked to the degree of heavy metal pollution. Generally, pollution of soil and water by heavy metals may lead to a decrease in microbial diversity. This is due to the extinction of species sensitive to the stress imposed, and enhanced growth of other resistant species. The sources of pollutant as well as long period of exposure are also the important factors regulating stress and fungal adaptation. In determining the tolerance of the fungi isolated and characterized from land fill and waste water, three common and dominant chromium sulphate solution tolerance fungi isolated belonged to the genera of *A. niger, R. nigricans* and *Penicillium* sp. They were spotted for tolerance of chromium sulphate concentration of 4.0% as well as their clearance zone test so as to dictate their cellulolytic activity on solid media as seen in Table 5. On the basis of these tolerance and clearance zone, they were tested for protease /cellulase activities. The isolates were purified through repeated streaking onto casein agar plates. Among the isolates, the organisms were selected based on highest zone formation (casein hydrolysis) on casein agar. The potential strains were maintained on agar slants and stored at 4°C in readiness for protease/ cellulose activity determination. Prepared broth culture of the three selected fungi (*R. nigricans, A. niger* and *Penicillium* sp) and their cleared zone with more than (++) on solid agar using state fermentation on locally available modified rice husk medium (MRHM) modified sawdust (MSDM) and control medium that is, potato dextrose medium (PDM). The culture organisms were incubated for 0, 15, 30 and 45 days at 32°C. There was a gradual increase in protease/ cellulose activity in the solid state fermentation up to 45 days while in the submerge, it shows rapid growth of protease/cellulose activity at maximum of 15 days and later got depleted beyond. *R. nigricans* isolate exhibited higher maximum protease/cellulose activity (2.8 IU/ml) on modified rice husk followed by *A. niger* (1.82 IU/ml) on saw dust and least was observed on *Penicillum* sp respectively in comparison to control (PDM) soluble as seen in Figures 1, 2 and 3 respectively. The possible explanation to these selected fungal serving as promising protease/cellulase producing organisms for further studies. In tanneries, such isolates may be useful for dehairing and bating processes during tanning operations and also for hydrolysis of proteinaceous waste in the discharged tannery effluent (Sivaprakasam et al., 2011). Soil is an important sub - system of the terrestrial ecosystem. The direct discharge of industrial effluents, especially without treatment, to soil may alter its biological properties. The discharge of effluent from tannery industry containing hazardous heavy metals affects microbial population in soil.

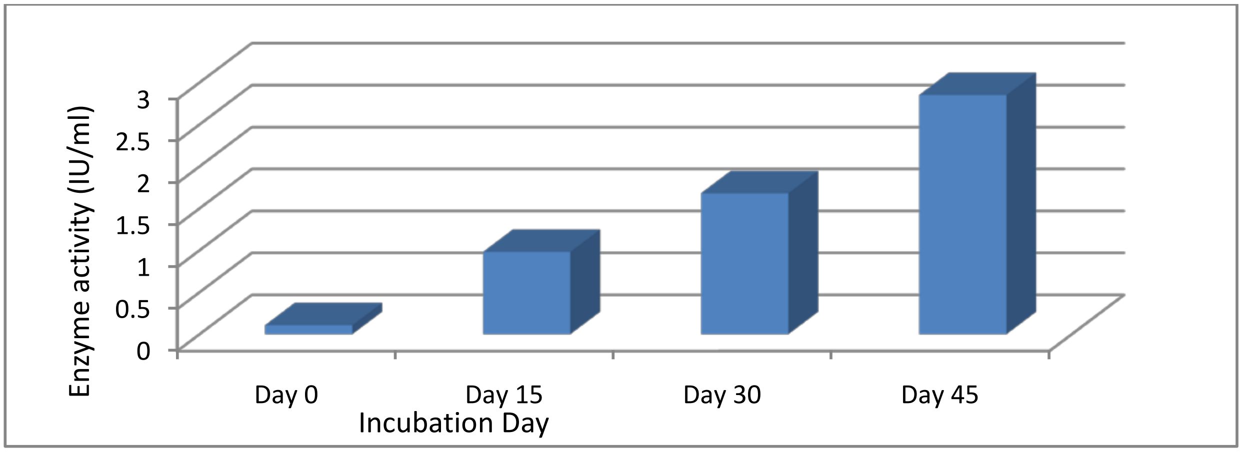
The fungal cultures isolated in the present investigation need to be further studied in depth for their proteolytic/cellulolytic potential to be exploited for conversion of proteose/cellulose waste materials into value-added and useful products.

Conclusion

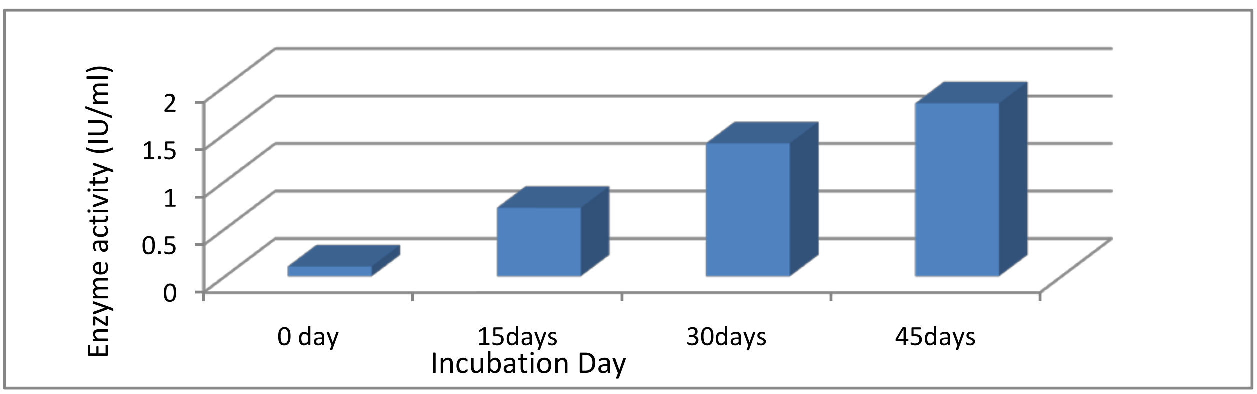
Strains of pectinolytic cellulolytic fungi including *R. nigricans* and *A. niger* have been isolated from control and polluted landfill in Challawa Industrial Estate, Kano State of Nigeria. Rice husk waste and sawdust waste have been identified as a low-cost substrate for pectinase/cellulase production in comparison with potato dextrose medium as submerge fermentation by the strains *R. nigricans* and *A. niger*. In other words, higher levels of pectinase activity were obtained by SSF compared to SmF. The use of modified rice husk for pectinase production will not only reduce the production costs of enzyme but also help decrease pollution load due to the agro-industrial waste. Further studies are to be conducted in depth for their cellulose waste material to be converted to value added and useful product.

Conflict of Interests

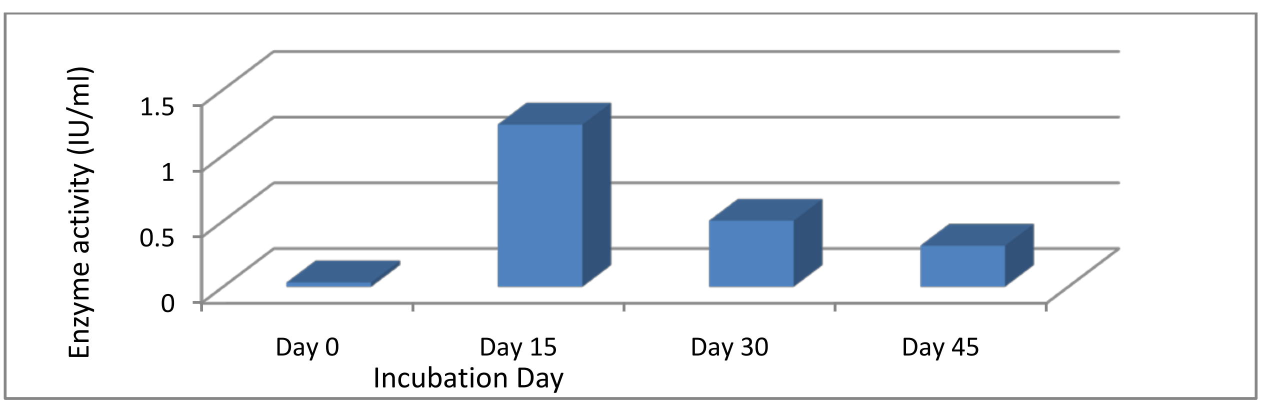
The author(s) have not declared any conflict of interests.



Culture filtrate of (*Rhizopus nigricans*) on modified rice husk.

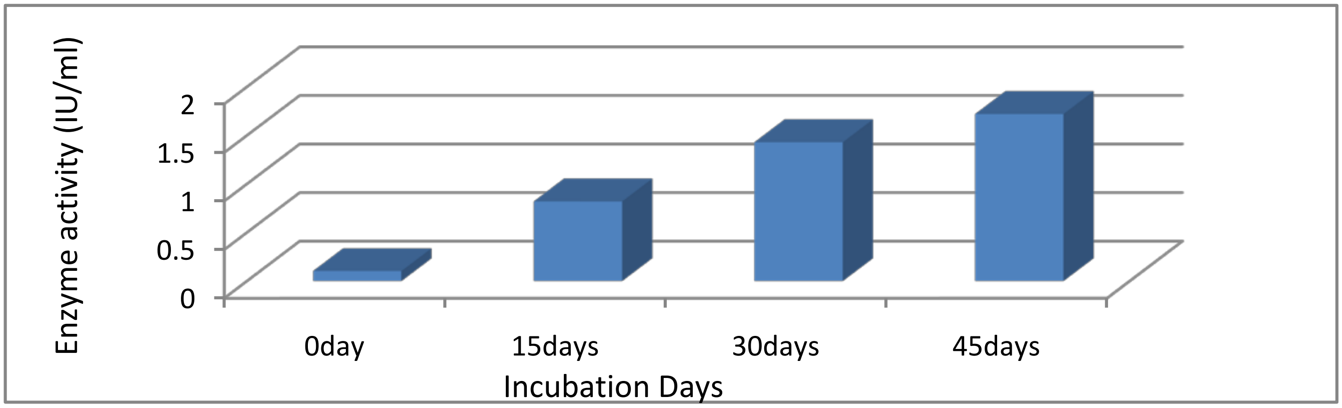


Culture filtrate of (*Rhizopus nigricans*) on modified saw dust.

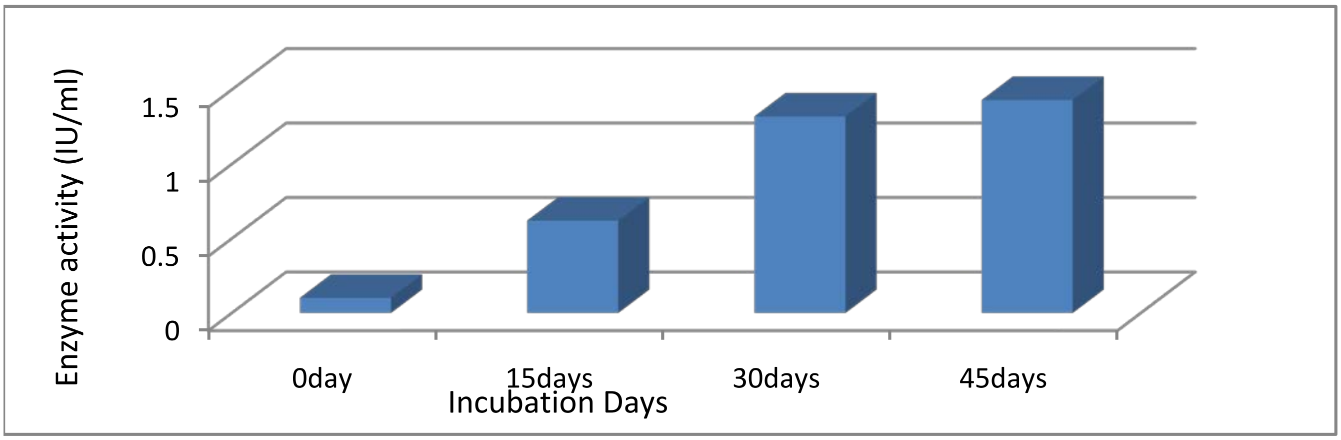


Culture filtrate of (*Rhizopus nigricans*) on Potato dextrose medium.

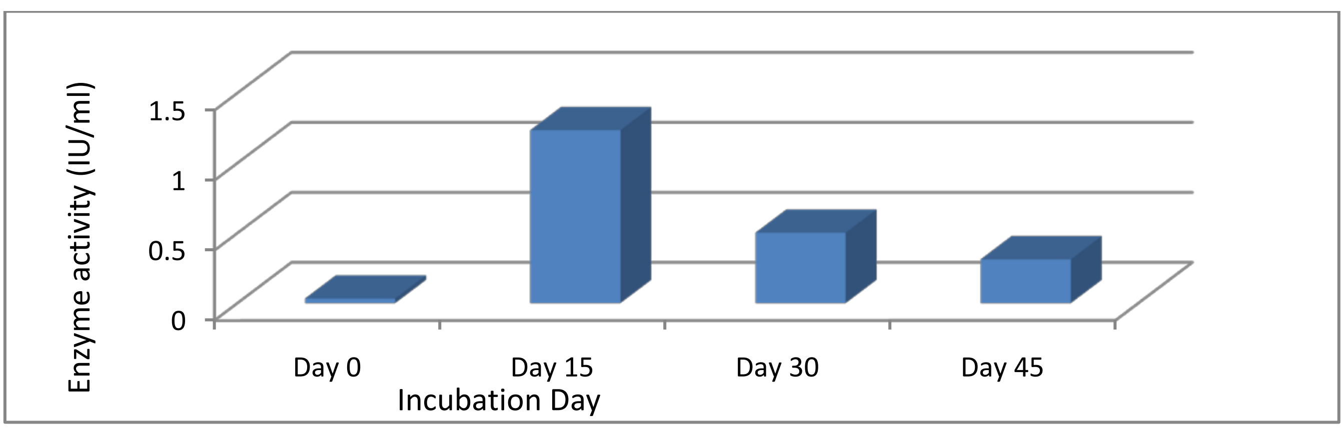
Figure 1. Enzyme estimation from culture filtrates of *Rhizopus nigricans*. Reveals that amount of protease/ cellulose was increase with increase in incubation time up to 45 days on both modified rice husk and sawdust (2.8 IU/ml) and (1.82 IU/ml) respectively in comparison with the control medium which shows an increase of the activity at maximum of 1.23 IU/ml for 15 days and decrease to 0.312 IU/ml at 30 days.



Culture filtrate of (*Aspergillus niger*) on modified rice husk medium

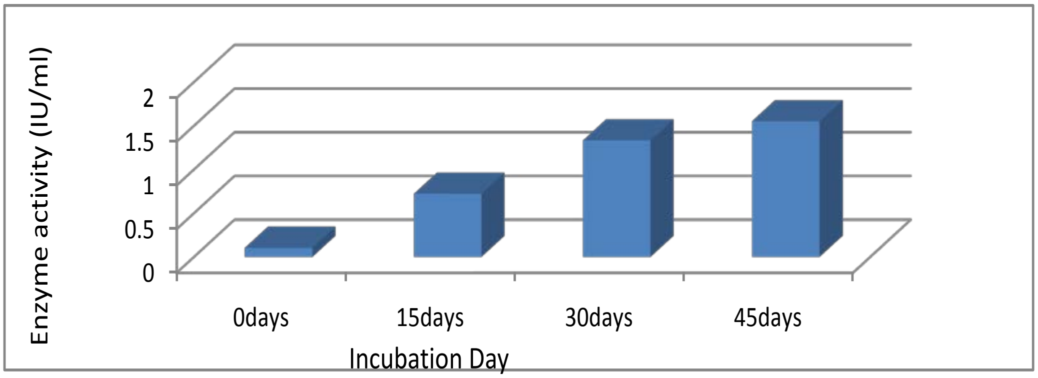


Culture filtrate of (*Aspergillus niger*) on modified saw dust medium

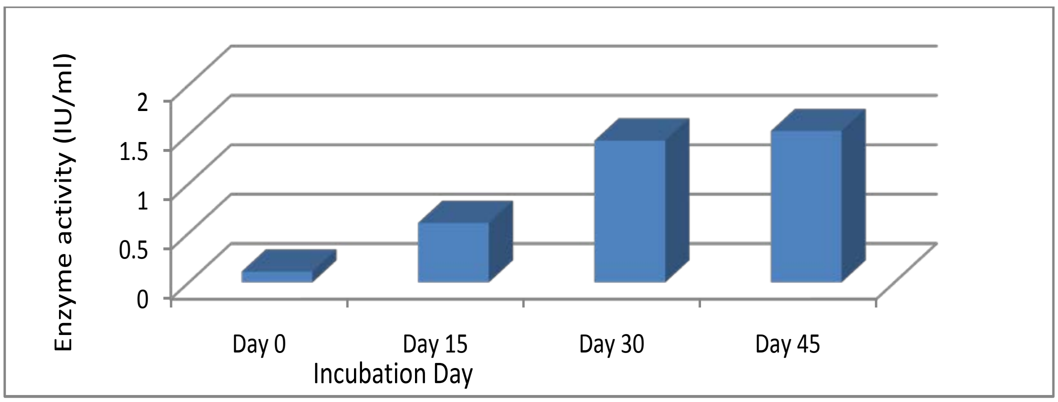


Culture filtrate of (*Aspergillus niger*) in Potato Dextrose Medium

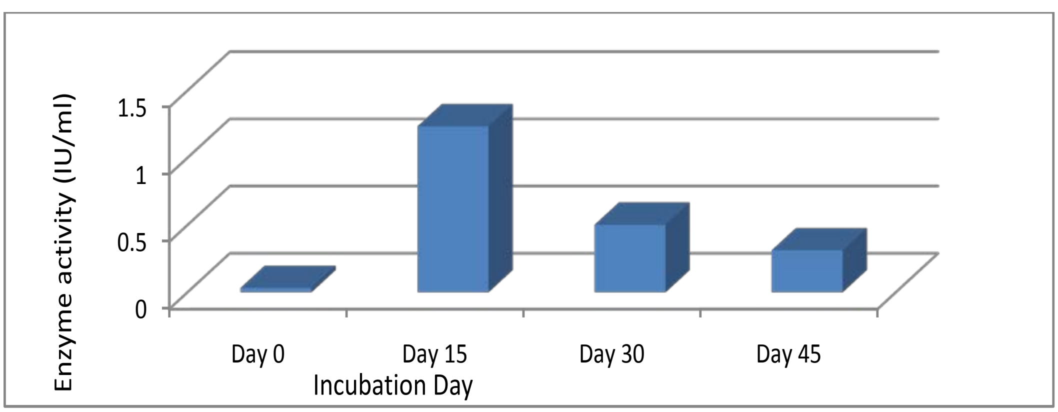
Figure 2. Enzyme estimation from culture filtrates of *Aspergillus niger*. Reveals that the amount of cellulase product was increase with increase in incubation time up to 45 days on both modified rice husk and sawdust (1.72 IU/ml) and(1.43 IU/ml) respectively in comparison with the control medium which shows an increase of the activity at maximum of 1.23 IU/ml for 15 days and decrease to 0.24 IU/ml at 30 days.



Culture filtrate of (*Penicillium* sp) on modified rice husk medium



Culture filtrate of (*Penicillium* sp) on modified saw dust medium



Culture filtrate of (*Penicillium* sp) on potato dextrose medium

Figure 3. Enzyme estimation from culture filtrates of *penicillium* sp. Reveals that amount of protease/ cellulose was increase with increase in incubation time up to 45 days on both modified rice husk and sawdust (1.55IU/ml) and(1.34IU/ml) respectively in comparison with the control

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REFERENCES

Abd-Elzaher FH, Fadel M (2010). Production of Bioethanol via Enzymatic Saccharification of Rice Straw by Cellulase Produced by Trichoderma Reesei under Solid State Fermentation. New York Sci. 3:72-78.

Adawiah BI (2008). Isolation, Characterization and Identification of Microorganism from Soil Contaminated with Pesticides. A Thesis Submitted to Faculty of Chemical and Natural Resources Engineering, University Malasiya, Pahang, pp. 18-19.

Alvarez-Bernal DSM, Olalde-Portugal JT, Contreras-Remos N, Trujillo-Tapia V (2006). Effect of tanneries waste water on chemical and biological soil characteristics. Appl. Soil Ecol. 33:267-277. http://dx.doi.org/10.1016/j.apsoil.2005.10.007

APHA-AWWA-WEF (2000). Standard methods for the examination of water and waste water, 20th Edn. American Public Health Association, American Water Works Association. Water Federation, Washington DC.

Bolon NST, Rowarth M, Delaluzmora D, Curtin D (2008). Biological transformation and bioavailability of nutrient elements in acid soils as affected by liming Develop. Soil Sci. 32:413-446.

David shyambabu S (2010). Protease and protease and phaspatase activity of soil contaminated with dairy waste water Asian J. Microbiol. Biotechnol. Environ. Sci. 26:711-714.

Espinola A, Adamiam R, Gome LMB (1999). An innovation technology: Natural coconut fibre as adsorptive medium in industrial waste water clean up waste treat. Clean Technol. Proc. 3:2057-2066.

Gbolagunte GO, Okonkwo EM, Okizie NO, Silas DE (2003). Biotechnological detoxification of chrome from tannery waste: Preliminary studies. Nig. J. Biotechnol. 12(1):9-17.

Haiji M, Rebai A, Gharsallah N, Nasri M (2008). Optimazation of alkaline protease production by Aspergillus clavatus ESI in Mirabilis jalapa tuber powder using statistical experimental design. J. Appl. Microbiol. Biotechnol. 79:915-923. http://dx.doi.org/10.1007/s00253-008-1508-0

Janick KJ (2008). Parkia biglobosa: African Locust Bean. The encyclopedia of fruit and Nuts, Willingford U.K CABI North American Office, pp. 395-400.

Kamini NR, Hemachander C, Sandana–Mala JG, Puvanakrishnan R (2010). Microbial enzyme technology as an alternative to conventional chemicals in leather Industry. Curr. Sci. (Bangalore) 77(1):80-86.

Lederberg J (1992). Cellulases. In: Encyclopaedia of Microbiology (Vol. 1; A-C). Academic Press, Inc.

Lynd LR, Weimer PJ, Pretorius IS (2002). Microbial cellulose utilization: fundamentals and biotechnolgy. Microbiol. Mol. Biol. Res. 66:506-577. http://dx.doi.org/10.1128/MMBR.66.3.506-577.2002

Madan M, Dhillon S, Singh R (2002). Production of alkaline protease by a UV mutant of Bacillus polymyxa. Indian J. Microbiol. 42:155-159.

Nagaraju LG, Narasimba B, Rangaswami V (2007). Impact of effluents of sugarcane industry on soil physicochemical and biological properties. J. Ind. Pollut. Contam. 23:73-76.

Narasimba GA, Sridevi A, Venkata SR, Rajasekhar B (1999). Effects of cotton gaining mill. Effluent on soil enzymatic activities and nitrogen mineralization in soil. J. Chem. Pharm. Res 3:126-137.

Nigam PS (2009). Production of bioactive secondary metabolites. In: Nigam PS, Pandey A, editors. Biotechnology for agro-industrial residues utilization. First ed. Netherlands: Springer, pp. 129-145. http://dx.doi.org/10.1007/978-1-4020-9942-7_7

Nizamuddin SA, Sridevi A, Narasimba G (2008). Impact of dairy factory effluents on soil enzyme activities. Eco. Environ. Conserv. 14:89-94.

Ntui VO, Uyuh EA, Urua IS, Ogbuv, Okpako EC (2012). Regeneration of Parkia biglobosa Benth: An important tree species. Afr. J. Microbiol. Biotechnol. Res. 2(1):167-177.

Olaniji A (2013). Locust Bean Products Non-wood News No.10 Retrieved http://www.Fao.org/docrep/005/y464e/y4640e02ht#paia 1309276.

Pandey PK, Verma Y, Choubey S, Pandey M, Chandrasekhar K (2008). Biosorptive removal cadmium from contaminated groundwater and industrial effluents. Bioresour. Technol. 99:4420-4427. http://dx.doi.org/10.1016/j.biortech.2007.08.026

Pothiraj C, Balaji P, Eyini M (2006). Enhanced production of cellulases by various fungal cultures in solid state fermentation of cassava waste. Afr. J. Biotechnol. 5:1882-1885.

Saeed A, Iqbal M (2003). Bioremoval of cadmium from aqueopus solution by black gram husk (Cicer arientinum). Water Res. 37:3472-3480. http://dx.doi.org/10.1016/S0043-1354(03)00175-1

Saeed A, Iqbal M, Akhtar MW (2005). Biosorption of heavy metals using rice milling by product. Characterisation and application for the removal of metals from aqueous effluents. Chemosphere 54:987-995.

Sivaprakasam S, Dhandapani B, Mahadevan S (2011). Optimization studies on production of a salt- tolerant protease from Pseudomonas aeruginosa strain BC1 and its application on tannery saline waste water treatment. Brazil. J. Microbiol. 42:1506-1515.

Sinsabaugh RL (1994). Enzymatic analysis of analysis of microbial pattern and process. Biol. Fertil. Soils 17:69-74. http://dx.doi.org/10.1007/BF00418675

Tarley CRT, Arruda MA (2004). Study on biosorption of Cr (VI) by Mucor hiemalis. Biochem Eng. J. 23:185-192.

Thiombiano DN, Lamien N, Dibong DS, Boussim IJ, Belen B (2012). The role of woody species in managing food shortage in Burkina Faso. Sechrasse, 23(2):86-93.

Vivian HL, Funkelstein D, Steven Bark J, Shinrong H (2008). Protease for processing proneuro peptides into peptide Neuro transmitters and hormones. Annu. Rev. Pharmacol. Toxicol. 348:393-423.

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Scientific Research and Essays

Full Length Research Paper

Retrofitting industrial in electrical motor type: A matter of energy efficiency and reduction of maintenance

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This report aims to identify, in terms of economic and technical aspects, an electric motor whose characteristics meet a proposed replacement of a direct current (DC) motor in an aluminum extrusion plant, whose preventive maintenance has in the last years, the problem of technical and operational orders. Data relating to the preventive maintenance of motors in operation were used to estimate the performance of an induction motor in combination with an inverter for speed and torque control. The advantages were determined, and the investment costs can be reduced by maintenance. It was observed that the market offers an innovative solution by the use of a permanent magnet synchronous motor (PMSM), which is a brushless, alternating current (AC) motor, with reduced dimensions, and offers the same power as a three-phase induction motor (TPIM). Joule losses in the rotor are negligible because the rotor is fit internally with rare-earth-doped neodymium-iron-boron permanent magnets, which also minimizes motor temperature, thereby increasing its useful life. Estimates determined that the gains derived from preventive maintenance would be even greater than those expected for the induction motor. Simulations conducted in MATLAB showed that, in terms of energy efficiency, the PMSM is presently the most appropriate replacement for the DC motor.

Key words: Brushless, permanent magnets, preventive maintenance, retrofitting, electric motor.

INTRODUCTION

The large increase observed recently in the consumption of aluminum is an indication of its importance in modern industry. It is the most important non-ferrous metal, and is among the most highly consumed annually.

While the general economy grows worldwide at an average rate of 4.5% per year, aluminum consumption worldwide increases at an average annual rate of 6.3%, according to the Department of Industry, Base Area Input, Basic National Bank Development, Economic and Social (Bndes, 2011).

Given this scenario, aluminum extrusion companies should seek to improve their methods and processes to meet this rising demand. Improvement requires companies to minimize losses by reducing equipment downtime owing to machine failure, and in particular, downtime for preventive maintenance, which in the case of direct current (DC) motors is expensive and requires prolonged machine downtime. Furthermore, to increase

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Figure 1. Cutaway description of a DC motor (INO, 2010).

their productive capacity, aluminum companies must modernize their equipment, seek technological upgrades of their facilities, increase energy efficiency, improve reliability, and reduce electricity and preventive maintenance costs. The development of power electronics and microelectronics using microprocessors and microcontrollers has contributed to the application of alternating current (AC) motors, which allow the implementation of complex functions with a shorter and shorter response time. A good example of such an application is a permanent magnet synchronous motor (PMSM), which achieves torque performance and speed commensurate with those of a DC motor. The new efficiency standards impose high values for efficiency and power factor even for low power electric drives (Florin et al., 2014).

Taking the aforementioned points into account, this paper presents an investigation about of technical and economic feasibility and the general approach of a proposed retrofit by replacing DC motors used in the aluminum extrusion industry with PMSMs. The question to be addressed by this study is whether a PMSM can offer the same speed performance and torque as those of a DC motor, while reducing machine downtime and enhancing overall efficiency. Economic stresses and competitive markets have resulted in many industries turning towards maximizing cost-savings and developing more efficient operations. In terms of operating machines, the objectives have been to reduce maintenance costs, increase useful life of equipment and prevent catastrophic failures (Mahajan et al., 2013).

This paper examine the motors used in the aluminum extrusion industry to power equipment known as a “puller,” which is an auxiliary piece of equipment that grabs and pulls the profile material from the initial extrusion, directing and accompanying it during the process. Use of this equipment avoids the complications associated with table profile cooling, as well as providing better quality and greater agility to the profile extrusion process. The proposed retrofit process seeks, reduce maintenance costs, and increase system reliability. What happens a lot is also performing a modification to raise the level of performance and quality of the machine (Azevedo, 2007).

Maintaining the operational condition of industrial equipment, preventing industrial risks and ensuring the safety of persons and assets are just some of the principal challenges for production firms. Maintenance has been recognized as a fundamental function in the company and is transferred from the cost center to the profit center, which has led to massive development of maintenance support systems (Morello et al., 2014).

TECHNICAL DESCRIPTION

Historically, DC motors have been used to control machines for which speed and torque control are necessary. The ease of control allows for the precise adjustment of speed and torque throughout the operating range; however, the operation entails the use of many moving parts such as switches, brushes, and brush holders and the need for forced ventilation. High maintenance costs and limited applications in hazardous areas are the main limitations associated with DC motors. Figure 1 shows a DC motor cutaway highlighting the moving parts, brushes, brush holders, commutator, tachogenerator, and armature winding.

The disadvantages of the DC motor and the evolution of power electronics have led the three-phase induction motor (TPIM) be the most common engine used in drives with speed control, and it is a more attractive option because of its lower maintenance costs (Grandinetti, 2013). Figure 2 presents a cutaway description of the

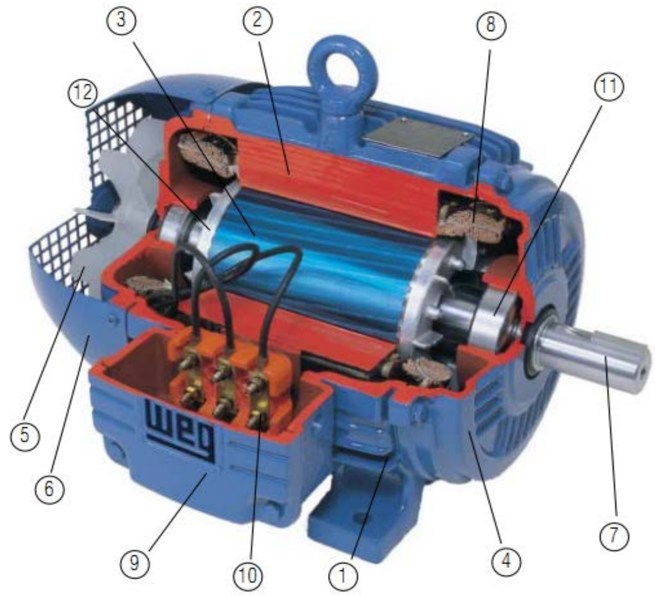

Figure 2. Cutaway description of the TPIM consisting of the following components: stator frame (1), laminated core (2), laminated magnetic core (3), end shields (4), fan (5), fan cover (6), rotor shaft (7), three-phase winding (8), connection box (9), terminals (10), bearings (11), short-circuit rings (12) (WEG, 2009).

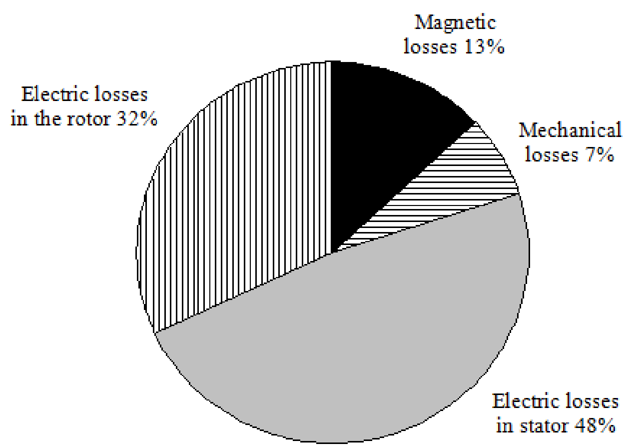

Figure 3. Losses in the TPIM (WEG, 2012).

TPIM consisting of the following described components and their functions. Stator: frame (1) is the supporting structure composed of a sturdy construction of cast iron, steel, or aluminum having high corrosion resistance and fins for heat dissipation; laminated core (2) silicon steel plates are heat treated to minimize eddy current losses; three-phase winding (8) consists of three sets of coils, one for each phase, forming a three-phase system. Rotor: shaft (7) transmits mechanical power; laminated magnetic core (3) plates have the same characteristics of the stator-laminated core plates.

Bars and rings: short-circuit rings (12) are single-piece injected aluminum. Other components of the TPIM are end shields (4), fan (5), fan cover, (6), connection box (9), terminals (10), and bearings (11) (WEG, 2009).

For applications involving fixed speeds, this type of motor is one of the best options. However, for applications in which it is necessary to control the speed and torque, this engine has some disadvantages, which translate into electrical losses such as, for example, the Joule effect on the rotor, which makes speed control difficult at slow speeds due to the increased operation temperature. Figure 3 depicts the losses of the TPIM.

In view of the background of the motors traditionally

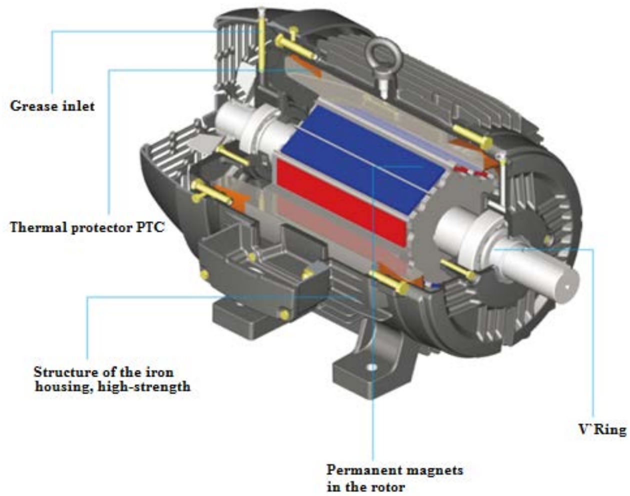

Figure 1. Cutaway of WEG's WMagnet with the following main components: grease inlet, thermal protector PTC, cast iron housing, permanent magnets, and V'ring (WEG, 2011a).

used in industry, this study sought other options highlighting the most advantageous use of motors with permanent rotor magnets.

THE PERMANENT MAGNET SYNCHRONOUS MOTOR (PMSM)

The PMSM is composed of a stator with three sets of coils arranged at 120°, and its rotor consists of permanent magnets. PMSMs are fed by an inverter voltage with frequency control. This allows for variable speed at constant torque, low vibration and noise, and high performance and reliability. These characteristics are fundamental for compressors, elevators, and conveyors. They are also attractive for applications in which there is limited space and a need to eliminate gearboxes, since it has reduced size and volume and can perform over a wide range of speeds. This motor suffers no Joule (RI^2) losses in the rotor, and therefore does not require ventilation, and heat dissipation is accomplished by natural convection. Its housing is necessarily shielded to protect the internal magnets against impurities (WEG, 2011b).

Figure 4 shows a cutaway description of the commercial motor manufactured by WEG, the WMagnet. The main components shown in the figure are as follows: grease inlet: device that allows for lubrication without stopping the engine, and in normal operation, the bearing lifetime is 100,000 h (SKF, 2007; SIEMENS, 2010); thermal protector PTC: responsible for feedback, the temperature of the stator winding to the control electronics; cast iron housing: supporting structure set with fins for heat dissipation; it is also composed of core silicon steel plates heat treated to minimize iron losses, three-phase winding has three equal sets of coils 120°

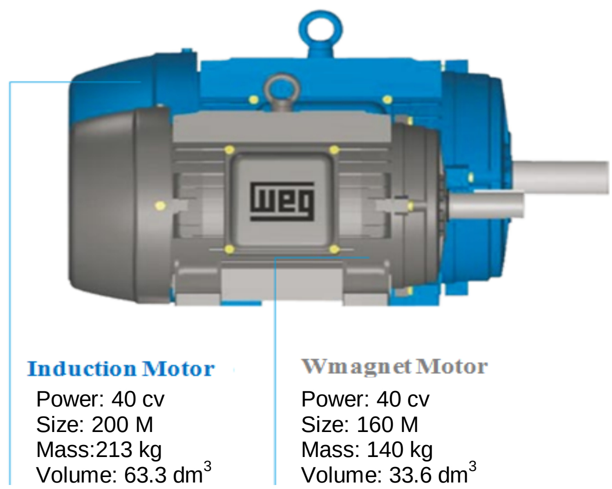

Figure 5. Comparison between TPIM and WEG's WMagnet PMSM (WEG, 2011a).

out of phase, forming a three-phase system; permanent magnets are composed of neodymium-iron-boron internally installed in pairs on the rotor, which reduces power losses by the Joule effect, and thus ensures a lower motor temperature; the V'ring is responsible for sealing the internal parts of the engine to prevent the penetration of impurities into the motor and to mainly protect the magnet. Most permanent magnet materials lack ductility and are inherently brittle. Such materials should not be utilized as structural components in a circuit (MMPA, 2000).

As a result, the volume and weight of WEG's WMagnet motor are lower than those of a TPIM of the same power, and the lifetime is significantly increased. Figure 5 shows a comparison between two motors of the same power,

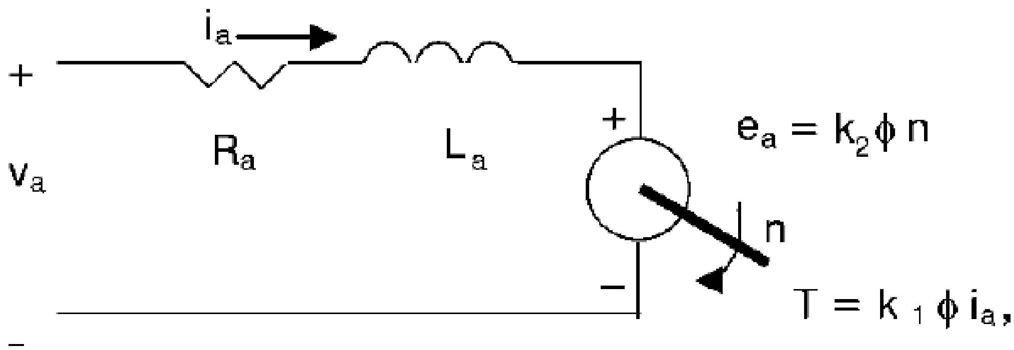

Figure 6. Equivalent circuit of the DC motor.

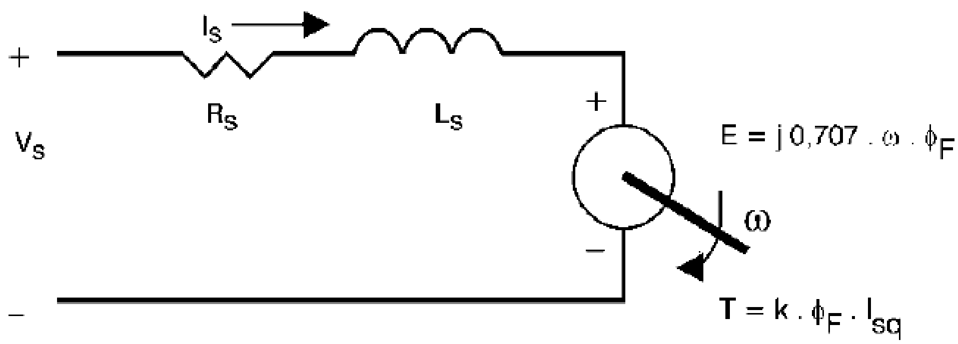

Figure 7. Equivalent circuit of a PMSM in stationary regime.

showing that the casing size, volume, and overall mass of WEG's are lower for WEG's WMagnet PMSM as compared with a typical TPIM.

ELECTRICAL CHARACTERISTICS

A comparison between Figures 6 and 7 show the similarity between electric synchronous of permanent magnet motors and DC motors. The PMSM however, present mechanical characteristics advantage over the DC motor, including: low maintenance (brushless), low inertia, feedback speed and greater relative power/volume, lower current and therefore temperature. Although the PMSM has similarity with DC motors, this has some complexity, including the condition of the field weakening as in DC and PMSM.

The torque of the DC machines is given by the relationship set forth in Figure 6 as

$$e_a = k_2 \phi n$$
$$T = k_1 \phi i_a,$$

Where T = torque; k_1 = a constant which depends on the characteristics construction of the machine; ϕ = magnetic flux; i_a = armature current.

Keeping ϕ constant, the torque can be directly modified by the current,

Where: V_a = armature voltage; R_a = armature resistance; L_a = inductance of armor;

And the back EMF is given by e_a,

Where: n = is the speed on the machine shaft; k_2 = constant dependent on the characteristics construction of the machine.

The decrease in the magnetic flux ϕ, maintaining the conditions of rated voltage and current, allows engine operating at higher rate than the rated speed, but with reduced torque. This can be concluded from observation of equations of electrical torque and EMF, with a reduction for ϕ to e_a and i_a constants. This mode operation is known as "weakening field "or as a region of" power available constant "(e_a and i_a= constant).

Synchronous motors with rare earth permanent magnets have higher power density than comparable DC motors because the limiting effects of the mechanical commutator are absent; the power density exceeds also that of induction motors because there are no losses by torque producing rotor currents that need to be removed by cooling (Leonhard, 2001).

The currents i_d and i_q of the stator current in synchronously rotating reference frame are analogous to the field current I_s and to the armature current I_a of the

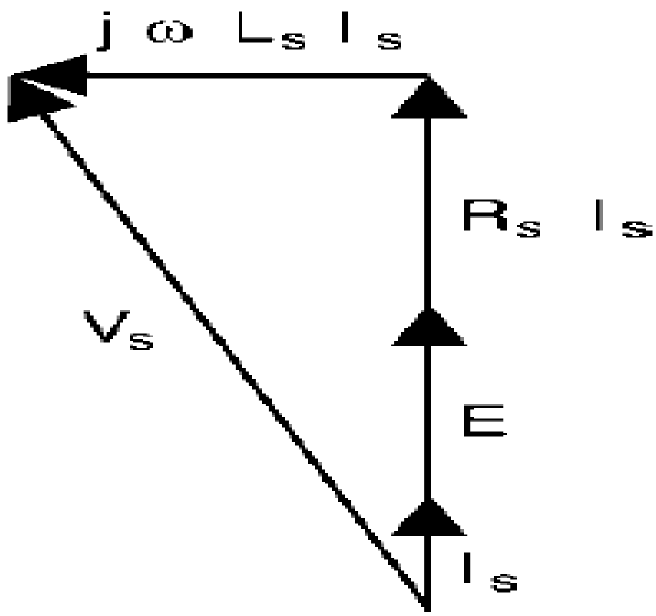

Figure 8. Phasor diagram on the condition of maximum torque.

DC machine (Sahoo and Ramulu, 2013).

The torque of the PMSM is presented in Figure 7 as:

$E = j\,0{,}707\,.\,\omega\,.\,\phi_F$

$T = k\,.\,\phi_F\,.\,I_{sq}$

Where T = electrical torque; k = a constant which depends on the characteristics construction;
ϕ = magnetic flux; I_{sq} = is a current flows in fictitious coil positioned towards the rotor and in the orthogonal direction to the rotor. "s" refers to the stator and "q" quadrature axis.

It can be shown that the equivalent circuit of this motor, the steady-state condition is presented as follows:

Where V_s = phasor voltage terminal; I_s = phasor of the armature current, Is = Isd Isq + j; R_s = stator resistance; L_s = stator inductance; ω = angular frequency of the supply.

One of the difficulties is that the PMSM do not admits naturally the weakening condition field as occurs with a synchronous machine rotor winding machine or with a current continuous excitation Independent or even with one induction motor. The corresponding vector diagram is shown in Figure 8.

The field weakening correspond to a ϕF decrease, which cannot be directly performed, because the field given by a magnet permanent. This hypothetical decrease would result a loss torque, but starting from, allow an increase in rotational speed, for amplitude of V_s constant, as can be concluded from Equations 1 and 2.

$$T = k\,.\,\phi_F\,.\,i_{sq} \qquad (1)$$

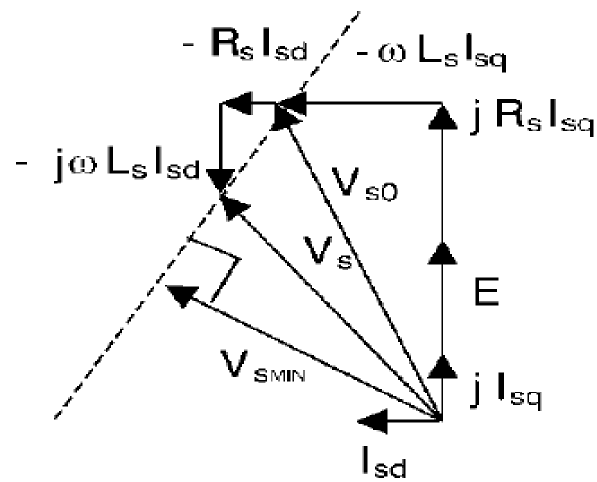

Figure 9. Phasor diagram in the presence of a negative component of I_{sd}.

$$E = j\,0{,}707\,.\,\omega\,.\,\phi_F \qquad (2)$$

The feature field weakening may be desirable in some applications where a rotation is necessary greater than the nominal torque request with reduced.

A similar effect to the field weakening PMSM, however, is obtained by imposing a negative component I_{sd}. The new diagram phasor corresponding to this situation is shown in Figure 9.

From the phasor diagram, we can see that this negative component of the current in the direction of the axis direct allows a decrease in the value of V_s. The place geometric end of the phasor is indicated V_s the dotted

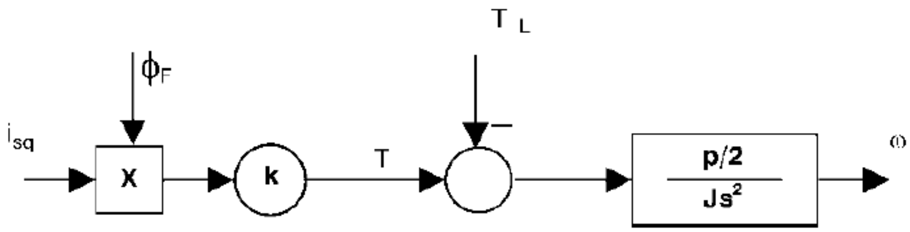

Figure 10. Block diagram of a permanent magnet synchronous motor.

Table 1. Information of the DC Motor and tachogenerator subject to retrofitting.

Information of the motor		Information of the Tachogenerator	
Model	MGL112M	Model	2R 60
Manufacturer	CEAR	Manufacturer	DEBU
Power	18,4 kW	Serial Number	6002068
U armature	400 V	Min. Tension	0.06 V
U field	220 V	n. Máx.	10000 min^{-1}
I armature	52 A	I. Máx.	0.25A
I field	2.3 A	IP	55
n nominal	2555 rpm	Direction	Reversible
M. de Inertia J	0.047 kgm^2	-	-
Reg. Service	S1	-	-
Torque	69 N.m	-	-

line in Figure 9. Minimum value occurs when V_s is perpendicular to this line. If | V_s | is kept constant, similar reasoning shows that a negative component I_{sd} leads to an increase of E and therefore the speed of rotation.

The torque given by Equation 1 is decreased because the presence of component I_{sd} implies a I_{sq} decrease in component so as to respect the maximum value of the total armature current | I_s |, given by:

$$|I_s| = \sqrt{I_{sd}^2 + I_{sq}^2} \quad (3)$$

This sequence, although not weak ϕF effectively corresponds to exactly one field weakening operation.

Anisotropic rotors is shown in Figure 4; the reactance of direct axis (ω, L_d) assumes higher values that the quadrature reactance (ω, L_q), like a machine with salient poles, allowing the field weakening with components I_{sd} minors.

The result of the low electrical modeling of PMSM is presented. The mechanical behavior of the motor is governed by Newton's equation:

$$T - T_L = J \,.\, (2/p) \,.\, (d^2\omega / dt^2) \quad (4)$$

Where TL = load torque; J = moment of inertia of the rotating parts; p = number of poles of the motor; ω = angular frequency of the power electric.

The equations worked in previous sections can be presented as a block diagram (Figure 10).

CHARACTERISTICS OF MAINTENANCE FOR MACHINE

Planned maintenance refers to periodic, often manufacturer specified, maintenance to check for signs of abnormalities. Condition Based Maintenance is typically performed when the need arises, when failure or a fault is imminent or when there is a noticeable decrease in performance (Mahajan, 2013). Nowadays, the global performance of the companies depends to a large extent on their performance in maintenance, but the increasing complexity and level of automation of the industrial equipment make it difficult for the users to operate, diagnose and maintain it efficiently. (Ruiz et al., 2014).

In search of a solution for the optimization of processes to meet the increasing market demand for aluminum, Exall Alumínio S.A., located in Pindamonhangaba - São Paulo - Brazil, decided to modernize their equipment, mainly because of high maintenance costs. Interventions to improve productivity and reliability of equipment are always needed, and it is a peaceful spot (Azevedo, 2007).

First, the puller had to be retrofit, which had been in continuous operation using a DC motor for over 15 years. Table 1 presents data from the motor nameplate and tachogenerator.

Table 2. Useful life of the lubricant for several bearings (WEG, 2012).

Bearings of the frame 90 up to 132 - open machines						
Useful life of the lubrification grease in hours						
Bearing	Rotation (rpm)					
	1.000	1.200	1.500	1.800	2.400	3.000
Horizontal axis						
6205-2 RS	20.000	20.000	20.000	20.000	20.000	17.000
6305-2 RS	20.000	20.000	20.000	20.000	20.000	17.000
6306-2 RS	20.000	20.000	20.000	20.000	20.000	15.000
6307-2 RS	20.000	20.000	20.000	20.000	18.000	13.500
6308-2 RS	20.000	20.000	20.000	20.000	16.000	12.000

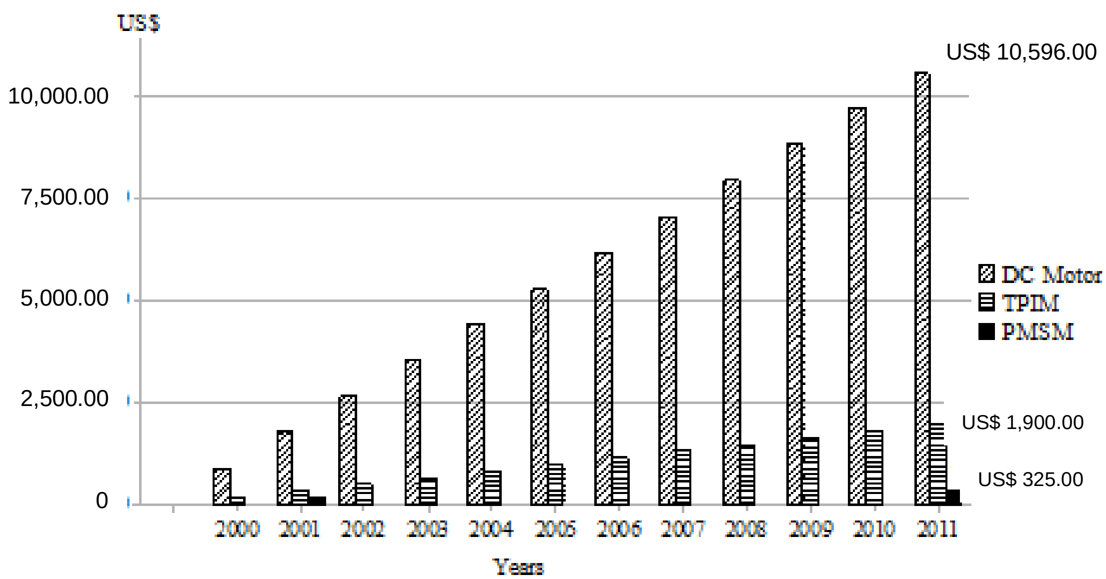

Figure 11. Accumulated costs of preventive maintenance for the DC motor, TPIM, and the PMSM (authors' design).

The manufacturer recommended replacing the bearings at the end of the useful life of the lubricant and setting the frequency of preventive maintenance to 12 months for an engine speed of 2555 rpm and bearings 6306 and 6308-ZZ-ZZ, as shown in Table 2. Since installation, the company always followed this schedule, and appropriate preventive maintenance was consistently performed on the DC motor. The cost of preventive maintenance for 2000 - 2011 is shown in Figure 6, with equivalent estimates for TPIM and PMSM.

The accumulated costs for the preventive maintenance of the DC motor during the period showed significant values. The maintenance of a TPIM is expected to be on the order of 18% of the amount spent on the preventive maintenance of the DC motor during the same period. On the other hand, the cost of maintenance of a PMSM is predicted to be on the order of 3% of the amount spent for the preventive maintenance of the DC motor during the same period measured. However, the PMSM also benefits from reduced heating, which increases the useful life of the lubricant, and permits the bearings to be replaced according to the manufacturer's recommendation of 95,000 h or 10 years of operation, the frequency range that defines preventive maintenance for PMSM. In addition, the grease nipple allows lubrication without stopping the motor, thus reducing downtime.

From the numbers presented in Figure 11, it appears that investing in new technology is an investment with a guaranteed return.

MEASUREMENTS AND SIMULATIONS

During analysis, it was found that the puller motor works in a low-speed high-torque region. Some measurements using an electrical equipment analyzer were subsequently conducted. The results generated the torque curve shown in Figure 12. It was observed that the critical point

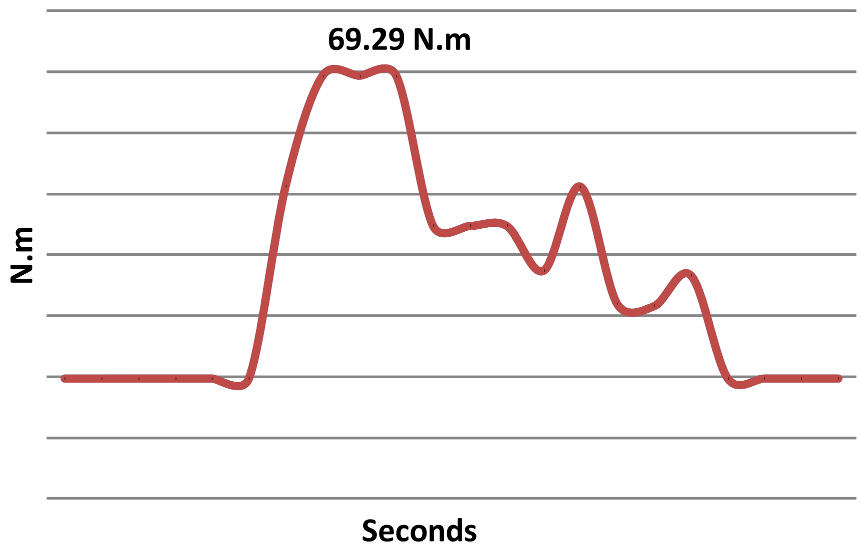

Figure 12. Torque of the DC motor over an operation cycle.

Table 3. Actual data collected.

T (N.m)	n (rpm)	t (s)
0	0	0
15	375	0.2
0	0	1
-15	-375	2
30	750	3
69	1725	4
0	0	5
-69	-1725	6
10	250	7
20	500	8

is the region of highest power and speed approaching the set point of the engine.

Before determining the best motor to replace the present DC motor, we decided to use the module and *Simulink* simulation software MATLAB (R2010a) to assistin the selection.

Simulations of the dc motor

The *Simulink* simulation environment was adjusted using the parameters collected in the field, actual data are machine cycle used in extrusion of aluminum profiles, as listed in Table 3, where *t* is the time in seconds, *T* is the torque in N·m, and *n* is the requested speed in rpm.

Figure 13 shows the circuit used for the simulation model of the DC motor. We attempted to fit simulations to the torque profiles collected in field trials and used some *Simulink* blocks for motor control aimed at determining and comparing the behavior of each of the motors tested.

For testing of the DC motor, we used a model of a three-phase, four-quadrant converter with torque proportional to speed, with closed-loop control for 25 Hp, independent power, armature voltage of 400 V, current armor of 52 A, rotation of 2555 rpm, field voltage of 220 V, and a field current of 2.3 A.

The converter is entirely built with standard *Simulink* blocks. Its output passes power control blocks before being applied to the DC motor block. The torque applied to the shaft of the machine is defined according to Table 3. As shown in Figure 14, simulation values of armature current, torque, and speed were calculated over 12 s. From the response of the DC motor, it is evident that efficient torque values are required by the system. One of the points of the simulation observed is the region where the torque is 20 N.m, where substantial torque is required at low speed, which, for the DC Motor, is not a problem because it has forced ventilation to ensure cooling. The values collected from DC motor simulations correspond well to the motor in actual operation.

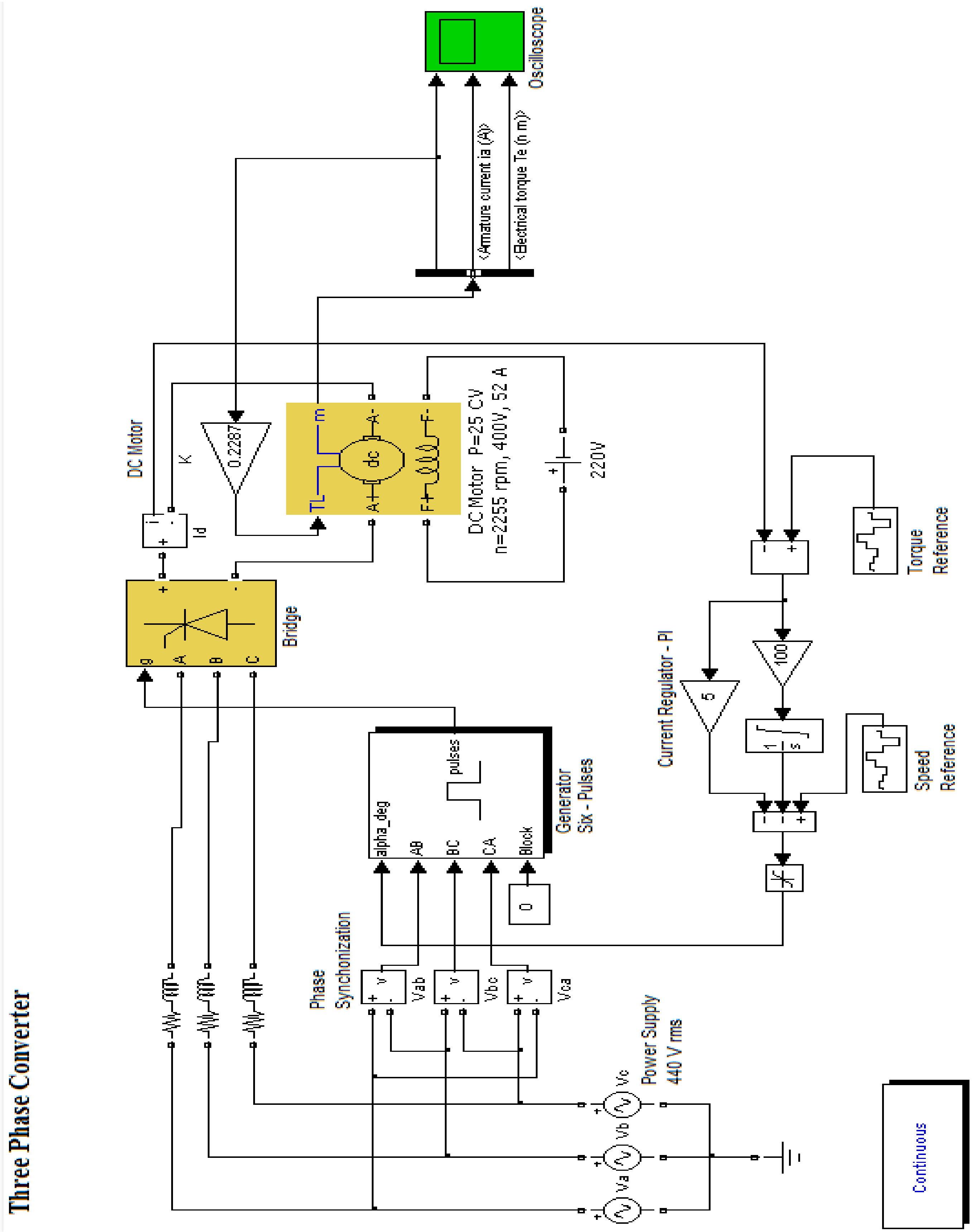

Figure 13. Three-phase four-quadrant converter model used in the simulations.

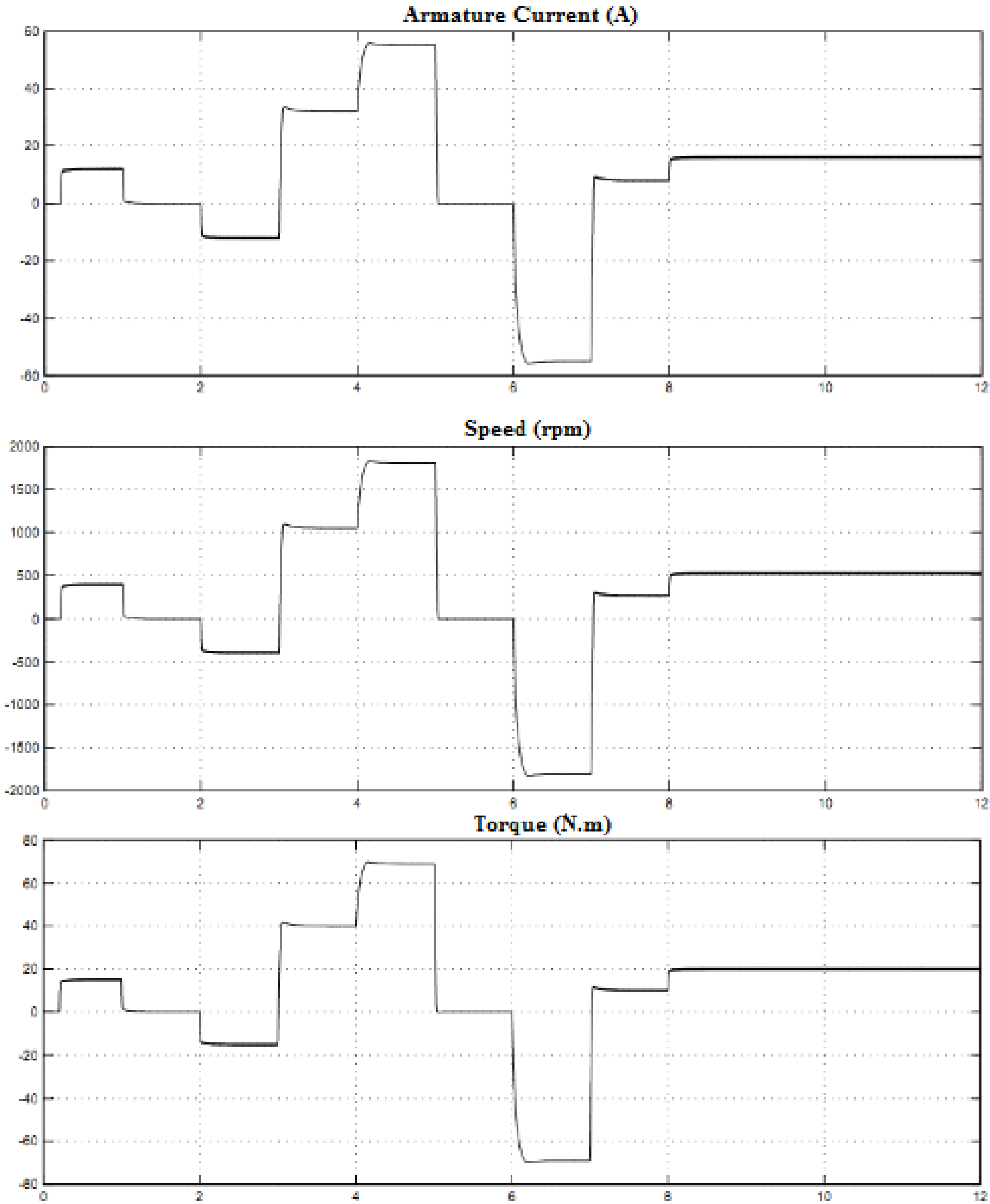

Figure 14. Values of armature current, speed, and torque collected from the simulations of the DC motor.

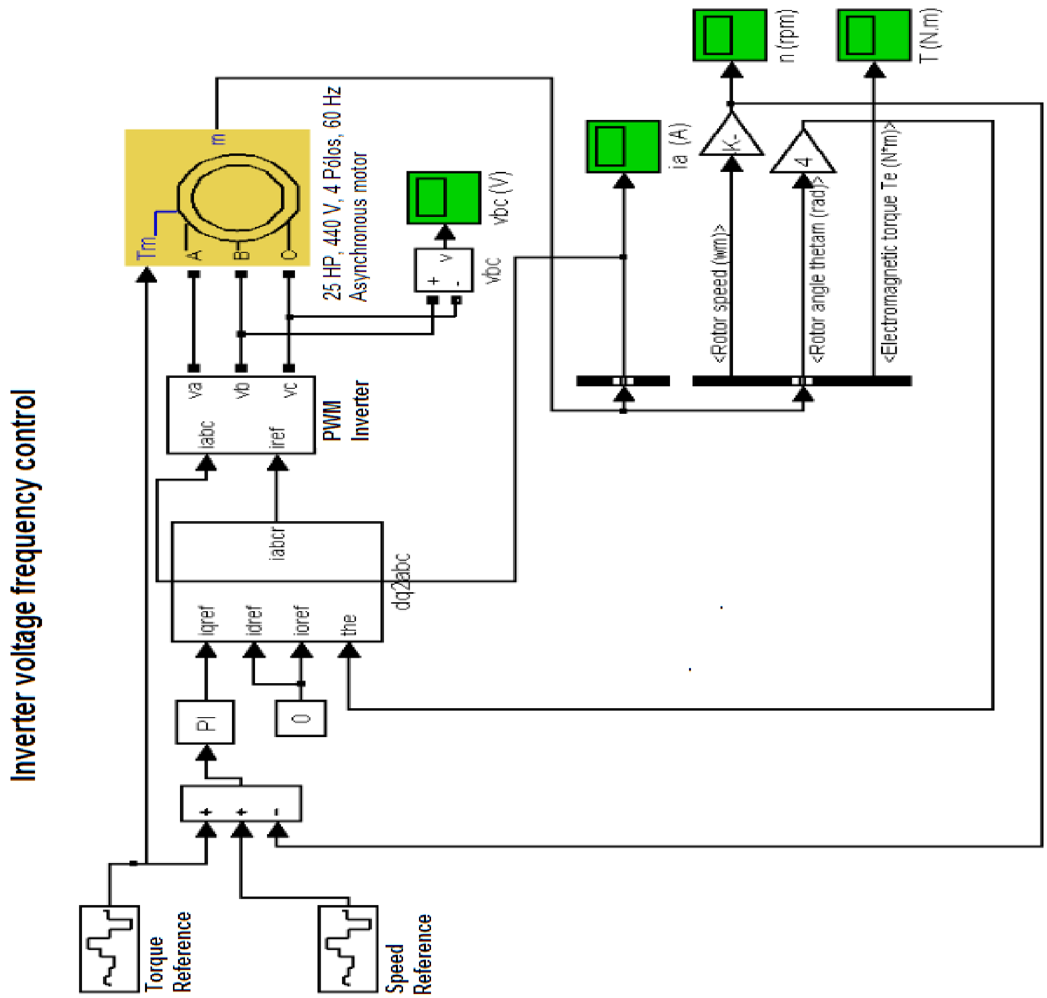

Figure 15. Inverter voltage with frequency control model used in the simulation of the TPIM.

Simulations of TPIM

Figure 15 shows the block diagram of the inverter model used in the simulation of the TPIM.

In order to ensure that the simulations were comparable, we used the same references and the same sampling period as shown in Table 3. The model of the inverter voltage with frequency control used in the simulation was built with standard *Simulink* blocks, whose motor parameters were as follows: power *25* CV, voltage 440 V, rated current of 32.3 A, and four poles. The model uses control feedback voltage and current, and torque is proportional to speed. As shown in Figure 16, the simulation values of stator current, torque, and speed were obtained over 12 s.

It can be observed that the TPIM response to speed values remained close to the values collected in the field. However, the rotor speed in the region of t > 9 s is low; the stator current reaches levels close to nominal values, and consequently causes a deficiency in ventilation, resulting in a temperature rise in the rotor and stator, which may even compromise motor insulation. A comparison of the characteristics of the DC motor with those of the TPIM indicates that the DC motor demonstrated faster response speed and torque. The speed of the TPIM was stable, but the torque was not reported with accuracy, suggesting that the rotor worked in a pulse. During the simulations sought to be the best parameter settings for TPIM who had the best representation of reality in the simulations.

Simulations of PMSM

Figure 17 illustrates the simulation model of the PMSM with closed loop control of voltage and current of a 25 HP motor for industrial applications, with a supply voltage of 380 V, rated current of 32.7 A, and a rotation of 1800 rpm. The PMSM inverter was entirely built with standard *Simulink* blocks, and the torque applied to the shaft of the

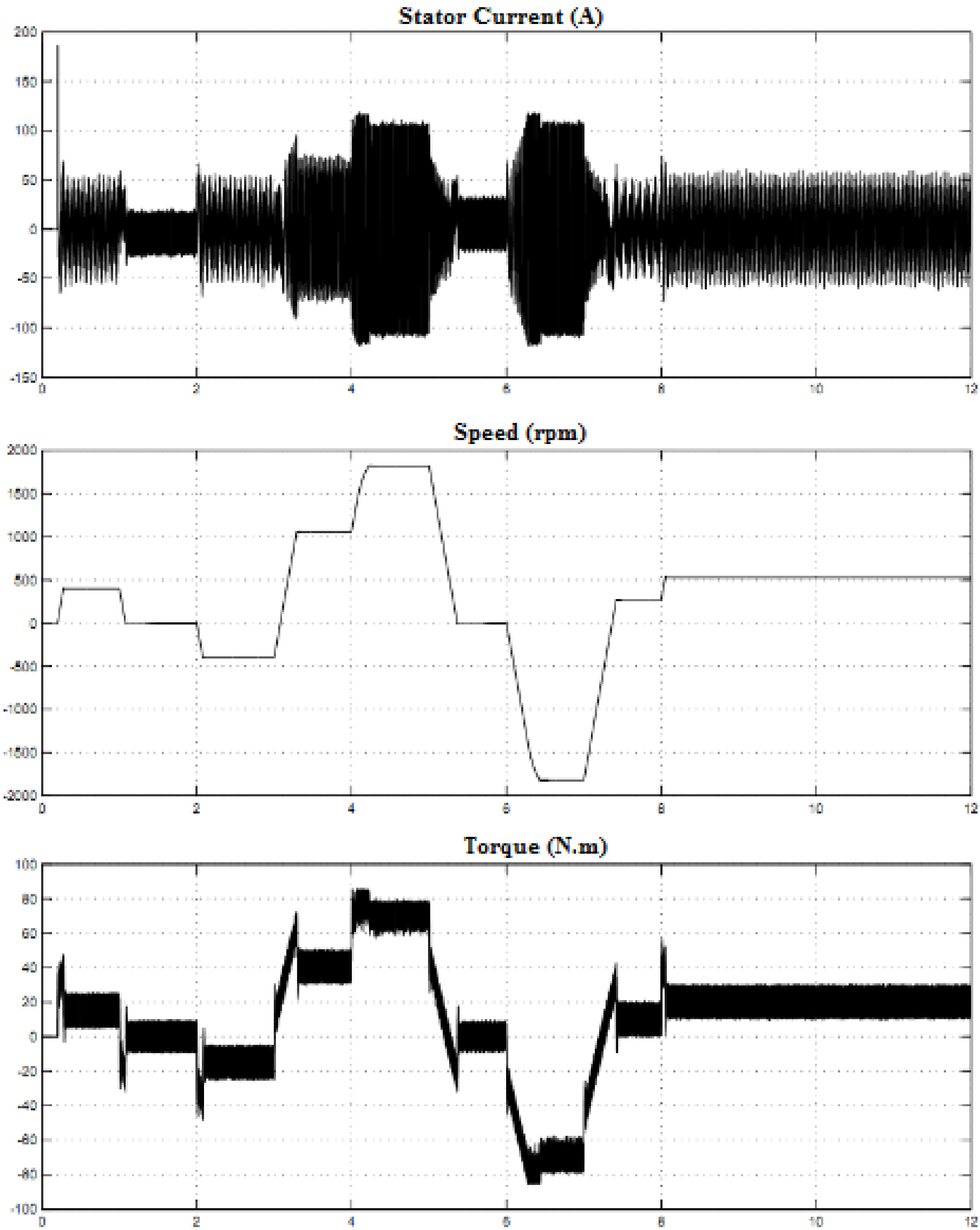

Figure 16. Values of stator current, speed, and torque collected from the simulations of the TPIM.

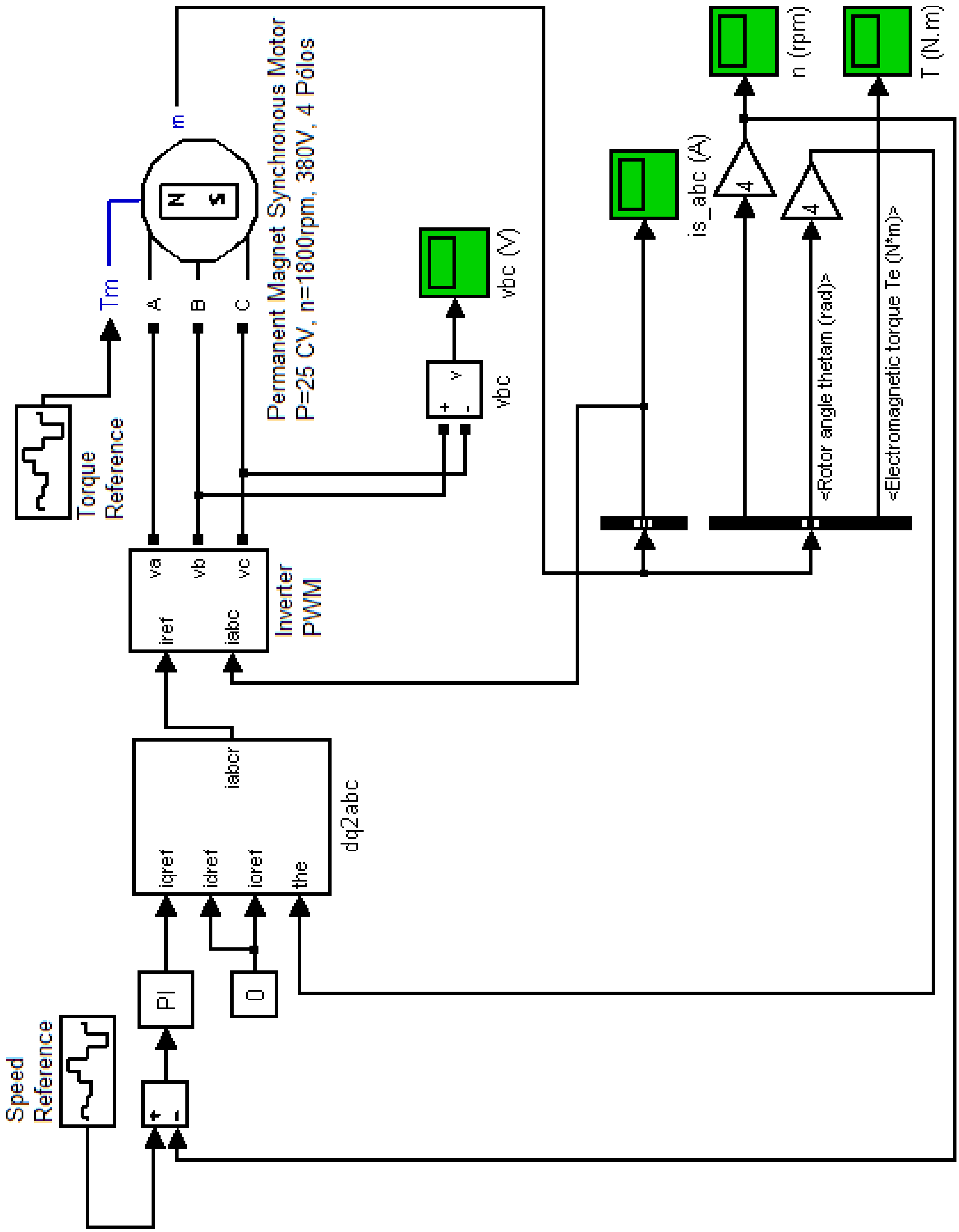

Figure 17. Inverter voltage frequency control model used in the simulation of the PMSM.

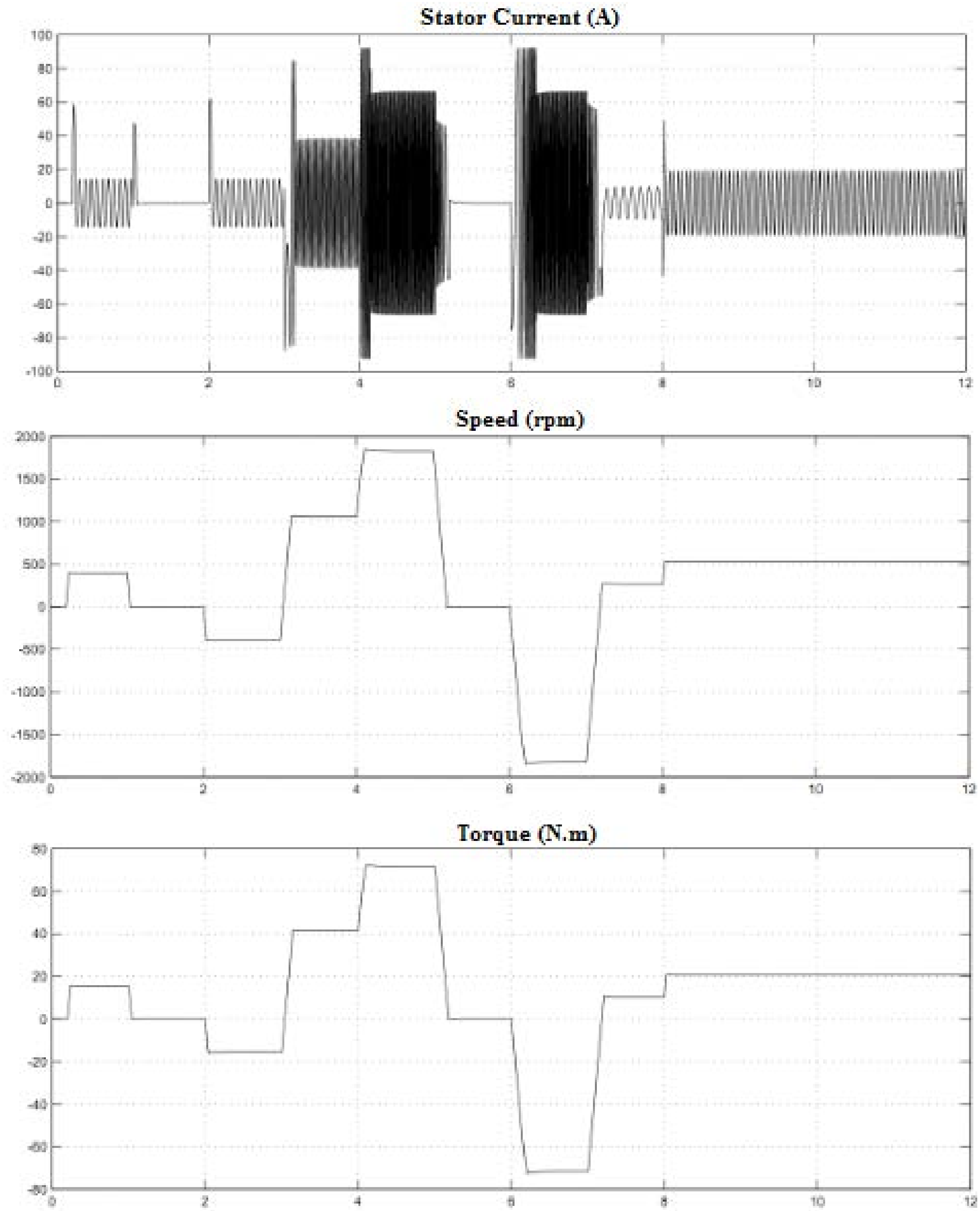

Figure 18. Values of stator current, speed, and torque collected from the simulations of the PMSM.

machine was set according to the values given in Table 3.

The results presented in Figure 18 demonstrate that the curves of speed and torque are maintained with a slight instability and were quickly corrected. The figure also indicates good stability and system response with

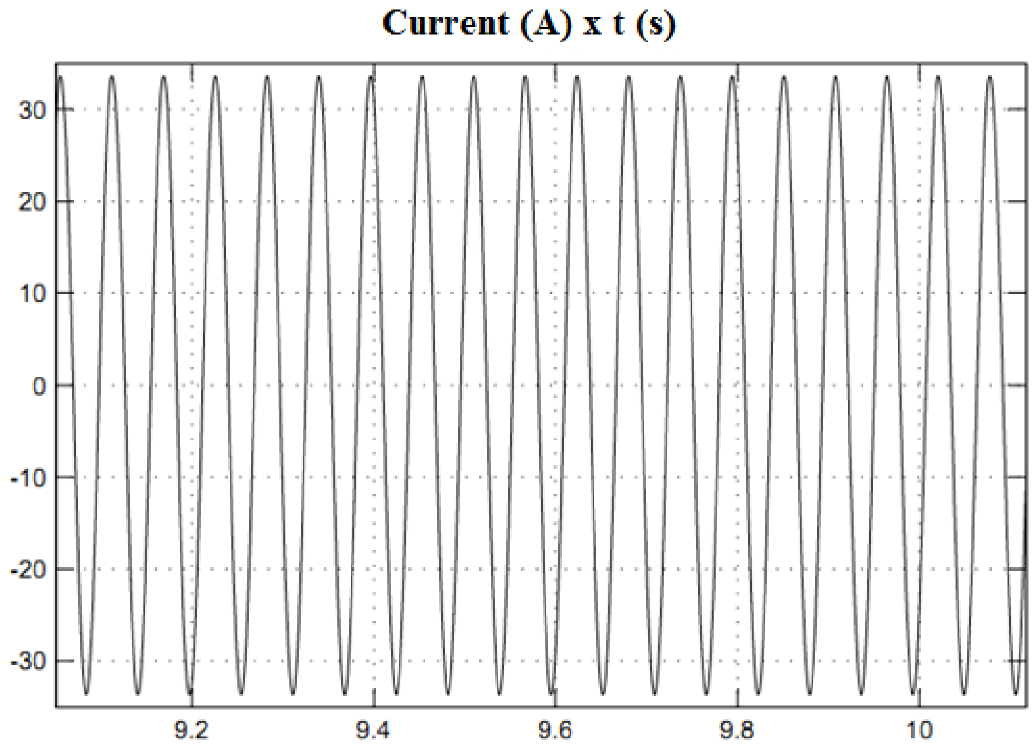

Figure 19. Stator current at a flux of 0.2 T and a torque of 20 N.m.

behavior similar to that of a DC motor. In the region of t >9 s, the torque is 20 N.m, the stator current remained close to 41% of the rated current, and the rotor speed is low, around 500 rpm, demonstrating that, for this type of motor, there is no problem associated with Joule losses in the rotor.

During the simulation, it was observed that by varying the flux linkage produced by the magnet rotor or replacing ferrite magnets with rare earth magnets, for example, caused the stator current to change dramatically. The Figure 19 shows a stator current of 35 A_p or 24.75 A_{rms} for a flux of 0.2 T and a torque of 20 N.m. With increased flux linkage to 0.9 T, maintaining a torque of 20 N.m requires, according to Figure 20, a current of 8.2 A_p or 5.8 A_{rms}.

The results summarized indicate that the application of the hybrid rotor resulted in an increase in the motor efficiency from 63% to 78% and an increase in the power factor from 0.68 to 0.97 (Slusarek et al., 2014).

From simulations, it was found that PMSM technology provides a higher gain compared to TPIM. Table 4 presents a comparison between a TPIM and a PMSM. It was found that, for the same power and torque, the PMSM has a reduced size. For example, for a power of 25 HP and a torque of 49.1 N.m, the volumes of the TPIM and Wmagnet PMSM housing are 160 M as housing 132 s, respectively. This smaller volume has become a significant benefit for the PMSM application.

Among other advantages of permanent magnets, there is an additional gain in yield of 92.8% for the TPIM and 94.6% for the PMSM for a power of 25 CV, as shown in Table 5. WEG's PMSM WMagnet was used for the retrofit objective of this study. According to the rotation and power data found in the catalog, as shown in Table 5, WEG's PMSM suitable for application to the puller is the model with the following specifications: 25 CV, 380 V, 4 pole, 132 M housing, torque 98.1 N.m, to yield 94.6%. For motor control, the manufacturer recommends using the CFW11 Inverter, which has a current rated at 38 A, an output voltage of 380 V, a 440 V supply, and inputs and control outputs compatible with existing control.

Conclusion

A study was conducted regarding the replacement of a DC motor with a PMSM for working under conditions of high torque at low speeds. It was found that, by eliminating Joule losses in the rotor, the PMSM operates at a low temperature, minimizes the fatigue of the moving parts, and increases the service life of bearings and lubricants. Another advantage is that PMSMs have lubrication points that allow the replacement of the lubricant without stopping the motor, thus increasing the period between preventive maintenance shutdowns. Owing to this combination, the preventive maintenance interval for PMSM is 95,000 h or 10 years, which is an

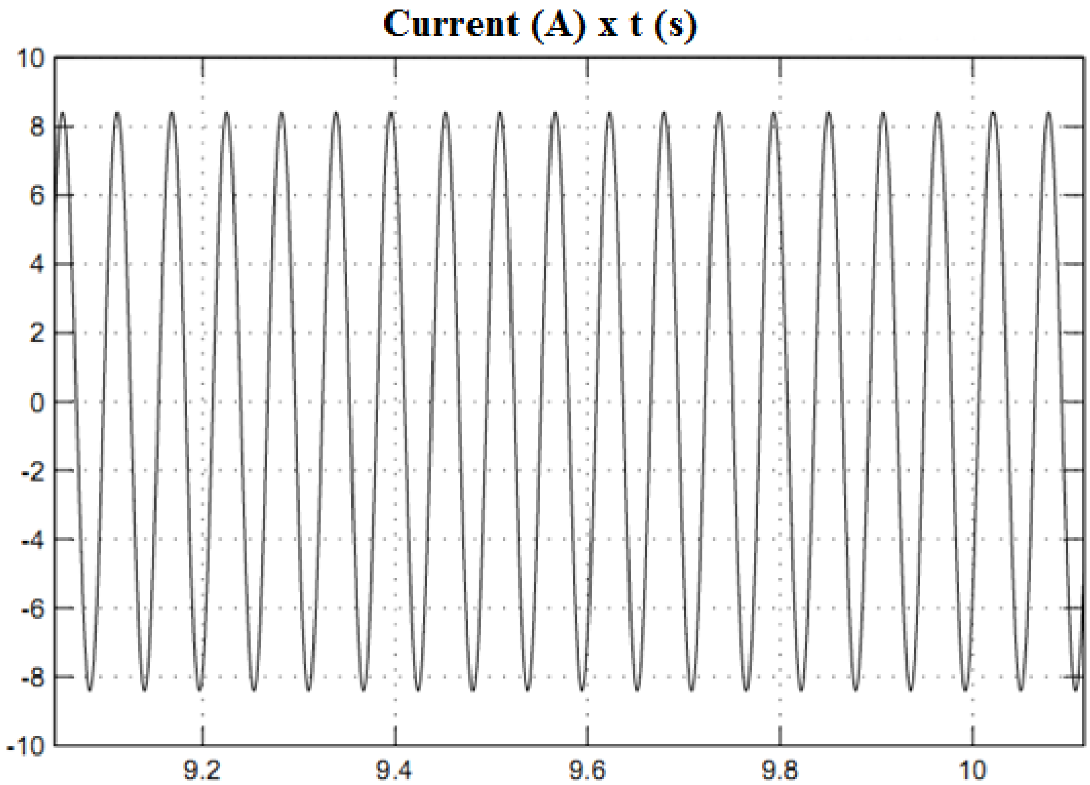

Figure 20. Stator current at a flux of 0.9 T and torque of 20 N.m.

Table 4. Comparisons between the TPIM and PMSM (WEG, 2011a).

Power (CV)	Torque (Nm)	Frame	
		Induction motor	Wmagnet motor
20	39.8	160 M	132 S
25	49.1	160 M	132 S
30	58.4	160 L	132 M
40	79.6	200 M	160 L
50	98.1	200 L	180 M
60	119.0	225 S/M	200 M
75	145.0	225 S/M	200 L
100	198.0	250 S/M	225 S/M

Table 5. Electrical characteristics of the 4-pole PMSM WMagnet (WEG, 2011a).

Motor							
Power		Frame	Torque (Nm)	Rated current in 380 V (A)	Efficiency (%)	Sound pressure level [dB(A)]	Weight of engine (kg)
CV	KW						
15	11	132 S	58.4	19.2	94.1	61	58
20	15	132 M	79.6	28.5	94.6	61	63
25	19	132 M	98.1	32.7	94.6	61	74
30	22	160 L	117.0	37.5	94.7	69	144
40	30	180 M	159.0	50.2	95.2	68	202
50	37	180 L	196.0	62.2	95.2	68	219

impressive number.

Associated with the motor, the sensorless vector inverter reduces mechanical connections of the angular position sensors, thereby minimizing mechanical failures, making the motor safe and reliable for applications where torque and variable speed are needed. It was found that the costs of preventive maintenance of PMSMs would be about 3% of DC motors, and about 18% of the TPIM.

The simulations indicate that the best engine for replacing the DC motor is the PMSM, which, in addition to meeting technical needs, preventive maintenance costs are minor and this guarantees a return on investment.

Conflict of interest

The authors are solely responsible for the material included in the article.

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REFERENCES

Azevedo C. (2007). If machines could talk. Ed. Saraiva, São Paulo, SP, Brazil. ISBN 9788502065932. [in Portuguese]

BNDES (2011). A indústria do alumínio estrutura e tendências. Disponível em:http://www.bndes.gov.br/SiteBNDES/export/sites/default/./set3302.pdf. [In Portuguese].

Florin L, Simion A, Livadaru L (2014). A F.E.M analysis for a 9/10 pole permanent magnet synchronous motor. IEEE Optim. Electr. Electron. Equipm. (OPTIM), pp. 409-414.

INO, T. E. M. Manual INO de Manutenção de Motores Elétricos de Corrente Contínua (2010). Manual INO de Manutenção de Motores Elétricos de Corrente Contínua. Disponível em: http://www.ino.com.br. [In Portuguese].

Leonhard W (2001). Control of Electrical Drives, Springer Verlag. http://dx.doi.org/10.1007/978-3-642-56649-3

Mahajan A, Vasudevan S, Calleija M, Scheding S (2013). Experimental platform for predictive maintenance of permanent magnet synchronous motors. IEEE International Conference on Computer Science and Automation Engineering (CSAE 2013).

MMPA (2000). Standard Specification for Permanent Magnet Materials. Disponível em: http://www.magnetsim.com/mmpa_standards.php?menu_id=30. [In Portuguese].

Morello BC, Karray MH, Zerhouni N (2014). PETRA: Process Evolution using a TRAce-based system on a maintenance platform. Knowledge-Based Syst. 99(68):21-39.

Ruiz PP, Foguem BK, Grabot B (2014). Generating knowledge in maintenance from Experience Feedback. Knowledge-Based Syst. 68:4-20. ISSN 0950-7051.

Sahoo SK, Ramulu A (2013). Salient features of vector control in AC motor drives: A review. Sci. Res. Essays 8(34):1649-1657.

SKF (2007). Setting the standard for performance and reliability, Disponível em: http://www.skf.com/binary/12-29536/6100_EN.pdf. [In Portuguese].

SKF (2005). Skf technical handbook for electric motors. Disponível em.

Slusarek B, Kapelski D, Antal L, Zalas P, Gwozdziewicz M (2014). Synchronous Motor with Hybrid Permanent Magnets on the Rotor. Sensors 14(7):12425–12436. Doi: 10.3390/s140712425. http://dx.doi.org/10.3390/s140712425

WEG (2011a). WMagnet Drive System, maio. Disponível em: http://ecatalog.weg.net/files/wegnet/WEG-wmagnet-drive-system-istema-de-acionamento-com-motor-de-imas-permanentes-50015189-catalogo-portugues-br.pdf. [In Portuguese].

WEG (2011b). Motor de Ímãs Permanentes e Inversor de Freqüência, set. Disponível em: http://ecatalog.weg.net/files/wegnet/WEG-motor-de-imas-permanentes-e-inversor-de-frequencia-artigo-tecnico-portugues-br.pdf. [In Portuguese].

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Scientific Research and Essays

Full Length Research Paper

Evaluation of the drying rate constant, drying efficiency, nutrients and sensory qualities of dried vegetables using solar dryer and open-air sun drying methods

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Utazi (*Gongromena ratifolia)* and Nchuanwu (*Occimum americanus*) were dried using solar dryer and open- air sun drying methods. 200 g of each sample was used. The weight losses were used to determine the reduction in moisture content. Drying was assumed to have taken place in the falling-rate period, which enabled the use of only one drying rate constant, K. Graphs of ln(M_0-M) versus time were used to obtain the drying rate constants, K for the two drying conditions. All analyses were done using standard procedures. The drying rate constants for the solar dryer and open- air sun dried Utazi were 0.8 and 0.7, respectively. Similarly, the values for Nchuanwu were 0 2 and 0.3, respectively. Moisture versus time graphs of both samples showed that the assumption of one falling- rate period is justifiable. The solar dryer was more efficient and would be more appropriate to industrial application. Both the nutritional and sensory qualities of the dried products were enhanced by the process.

Key words: Drying, solar dryer, drying rate constant, drying efficiency, nutrients, open-air drying.

INTRODUCTION

Drying has been recognized as the most useful processing technique for prolonging the keeping quality of solid foods including vegetables (Dissa et al., 2011). Utazi (*Gongromena ratifolia)* and Nchuanwu (*Occimum americanus***)** are both vegetables and belong to the class of agricultural food products often referred to as perishables. Their common feature is that they are abundant during the peak of their respective season but thereafter, become quite scarce (Onoja et al., 2012). They are well cherished spices especially in sub-Saharan Africa where they are widely used in preparations of various soups. They play quite significant role in our diets of the population because they are major sources of essential macronutrients, micronutrients and vitamins. Due to their seasonal nature and high moisture content, there is need therefore, to develop an appropriate technology for their preservation so as to guarantee their availability all year round (Eze and Chibuzor, 2008). Over

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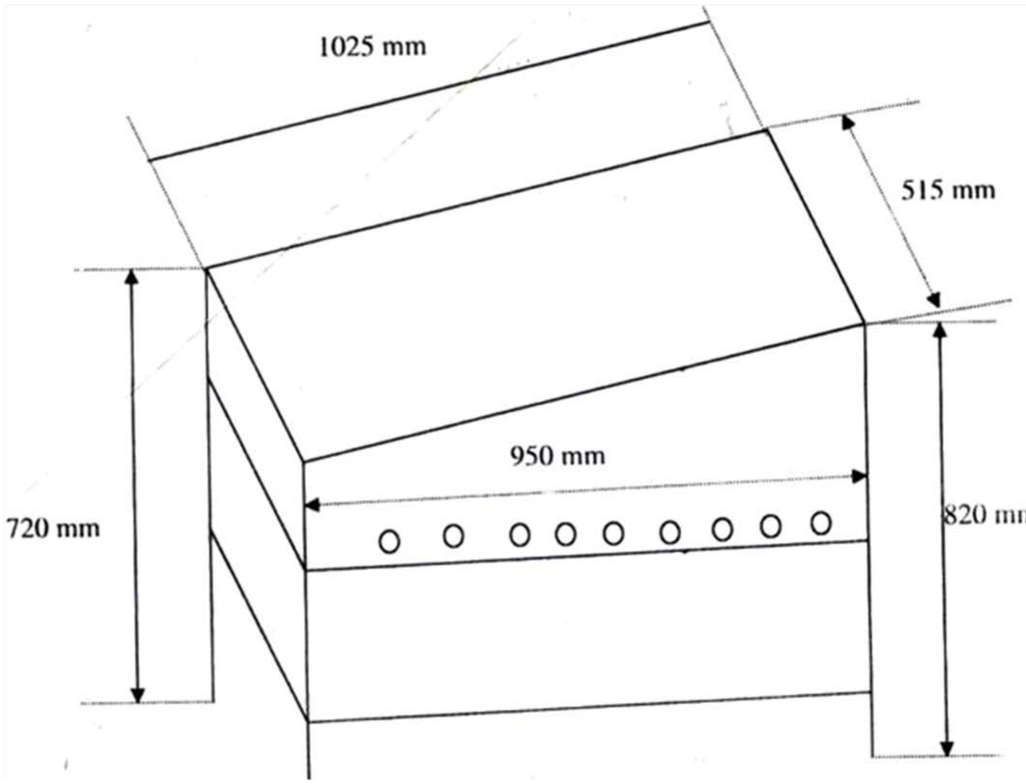

Figure 1. A schematic diagram of the passive solar dryer (National Centre of Energy Research and Development (NCERD), University of Nigeria, Nsukka).

the centuries, agricultural foodproducts including vegetables and spices are dried in the open-air sun or in certain parts of the chimneys designated for the purpose (Scanlin et al., 1997). Whitefield (2002) identified different types of drying techniques including electrical drying, open-air sun drying, firewood/fuelwood drying and solar dryer method. On comparative basis, open-air sun drying ranks first in terms of cost benefit but the poorest when variables such as protection against dust, rain and wind, insect infestation, microbial attack and nutrients retention are considered (Eze and Chibuzor, 2008; Anyanwu and Okonkwo, 2008; Oparaku, 2008).

Solar drying is an appropriate technology for a sustainable environment because it has the potential for high product quality (especially for such heat labile nutrient like ascorbate), it is inexpensive and most importantly, it is environmental friendly (Ekechukwu, 1989; Yaldiz and Ertekyn, 2001). A number of complex theoretical models to describe the heat and mass transfer phenomena in the drying of agricultural products have been described (Tongrul and Pehlivan, 2004; Doymaz, 2004; Mwithiga and Olwal, 2005; Sacilic et al., 2006; Anyanwu and Okonkwo, 2008)). These researchers have studied the kinetics of solar drying of agricultural products and observed that the process occurs in the falling rate period for most fruits and vegetables. The knowledge of drying rate constant is imperative for accurate prediction of drying rates according to the falling rate model. This information is very important to peasant farmers and industrial applications alike since specified levels of moisture content could be linked with a specified time in the process equation. The objective of the study was to compare the drying efficiency between solar dryer and open-air sun drying of agricultural products.

MATERIALS AND METHODS

Utazi (*Gongromena ratifolia)* and Nchuanwu (*Occimum americanus***)** used for the study were purchased at Ogige market, Nsukka. Each sample was divided into two equal batches of 200 g. One batch was subjected to open-air sun drying while the second batch was charged into a passive solar dryer supplied by the National Centre of Energy Research and Development (NCERD), University of Nigeria, Nsukka. The solar dryer measuring 1025 mm × 515 mm with glass cover uses natural convection principle (Ekechukwu, 1989; Anyanwu and Okonkwo, 2008). Its North end is 845 mm high while the south end is 720 mm high. The glass cover is inclined at an angle of 7° corresponding to the local latitude. The sides of the dryer are made of plywood perforated at intervals for effective air flow. Inside the solar dryer were lined thin perforated trays in layers (Figure 1).

Determination of proximate composition

The proximate composition of the samples was determined using standard techniques (AOAC, 1990). The ambient and drying chamber temperatures during the drying operations ranged between 22 to 35°C and 37 to 48°C, respectively. Samples were evenly spread during the drying operations to ensure effective drying in consonance with the thin layer model which describe the drying phenomena in a unified manner regardless of the controlling mechanism in the drying of agricultural products (Tongrul and Pehlivan, 2004;). The initial moisture contents of the samples were 72.4 and 65.4% for Utazi and Nchuanwu, respectively. They were weighed at intervals of two hours and the moisture content was calculated from the weight loss until a constant weight was obtained when the weighing was then terminated. The samples had to be carried to a sheltered place each time it rained. Samples were kept in desiccators at nights to prevent moisture re-absorption. The drying of each sample was done in triplicate.

Assumptions and mathematical consideration

In this study, we have assumed that drying occurs mainly in the falling rate period (Uretir et al., 1996; Karathanos and Blessiotis, 1997; Lashsasni et al., 2004; Anyanwu and Okonkwo, 2008). This enable**d** us to use the falling rate model (Equation 1). Moreover, it has been assumed throughout this work that the drying process was continuous and took place in one falling rate period, hence we employed only one rate constant. Couson and Richardson (1977) and cited by Anyanwu and Okonkwo (2008) observed that natural convection drying in the falling rate period can be represented by the following model:

$$dM / dt = e^{-kt} \quad (1)$$

Where, M = moisture content (%) at time, t (h); t = time; K = drying rate constant.

From the above it is obvious that:

$$dM = e^{-kt}dt \quad (2)$$

Integrating using appropriate limits we arrive at:

$$\int_{m_o}^{m} dM = \int_{t_o}^{t} e^{-kt} dt \quad (3)$$

Since the negative power of e shows that $M_0 > M$ and because $t_0 = 0$, we can write:

$$(M_0 – M) = e^{kt} \quad (4)$$

Where, M_0 is the initial moisture content (%) of the samples.

Applying the natural logarithms we arrive at:

$$\ln (M_0 – M) = Kt \quad (5)$$

Sensory evaluation

A -five point Hedonic scale where 5 represented the highest score and 1 the lowest was employed to evaluate the products (soups made from the dried vegetables) for taste, flavour, texture, colour and general acceptability. A 20- taste panel randomly selected from students and lecturers of the Department of Home science, Nutrition and Dietetics, University of Nigeria, Nsukka, participated in the tasting sessions. The tasting was carried out at the department. Each judge (panel member) was seated in an individual compartment free from noise and distraction. The soups were properly coded and served to the panelists.

Statistical analysis

The Statistical Package for Social Sciences (SPSS, version 17) was used to analyze the data. Means ±(SD) were calculated and Analysis of variance (ANOVA) were used to test the significance of the difference . The significance was accepted at $p<0.05$. (Cochran and Cox, 1992)

RESULTS

The results showed that while the percentage moisture loss by the open-air and solar dried samples were very close at the second day, the gap widened by the end of the third day. At the end of fourth day, it could be seen that the solar dried samples had lost virtually all its expellable moisture content as against the open-air sun dried samples. Moreover, the open-air samples had to be carried into a sheltered place each time it rained. However, this did not entirely prevent its weight from fluctuating as a result of the rainfall which occurred thrice during the period of the study. This is clearly visible from the graphs (Figures 2 to 6). Furthermore, analysis of the plots of $\ln(M_0 - M)$ against time (Figures 3 and 4) indicates that the rate constant for the solar dried samples are approximately 0.8 and 0.2 units per day while the open-air sun dried samples are approximately 0.7 and 0.3 for Utazi leaf and Nchuanwu leaf, respectively. With these values, it is quite possible to link a given level of moisture content with a specified drying time. This could be achieved either graphically or analytically using Equation (5).

The dry basis moisture content (X) versus time (t) graphs of both the open-air dried and the solar dried samples are also presented in Figures 5 and 6. Moisture content was calculated using Equations (6) and (7).

$$X = x^* x_t \quad (6)$$

Where x^* is the equilibrium moisture content (%). x_t is the moisture content corresponding to time, t.(h)

Ekechukwu (1999) and cited by Anyanwu and Okonkwo (2008) observed that x_t can be derived from the equation:

$$x_t = \frac{W - W_s}{W_s} \quad (7)$$

Where W = weight (g) before drying and W_s = weight (g)after drying.

The results also showed that drying resulted in improved proximate composition but decreased ascorbate and minerals of the samples (Tables 1 and 2).

The sensory attributes of the soups made from the dried samples were also enhanced (Table 3).

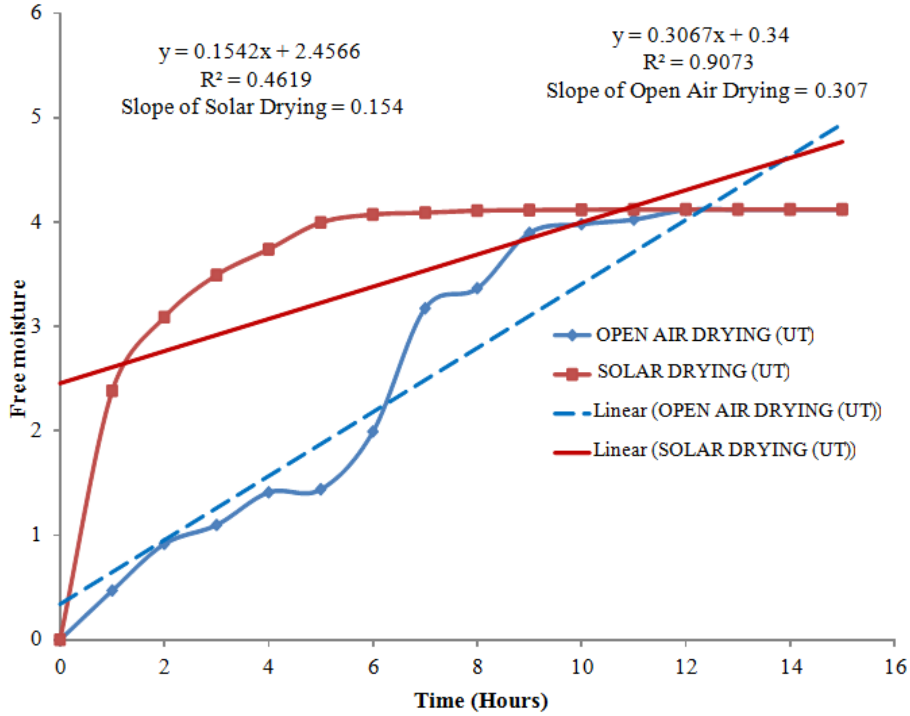

Figure 2. ln(Mo-M) versus time(t) graphs for utazi sample.

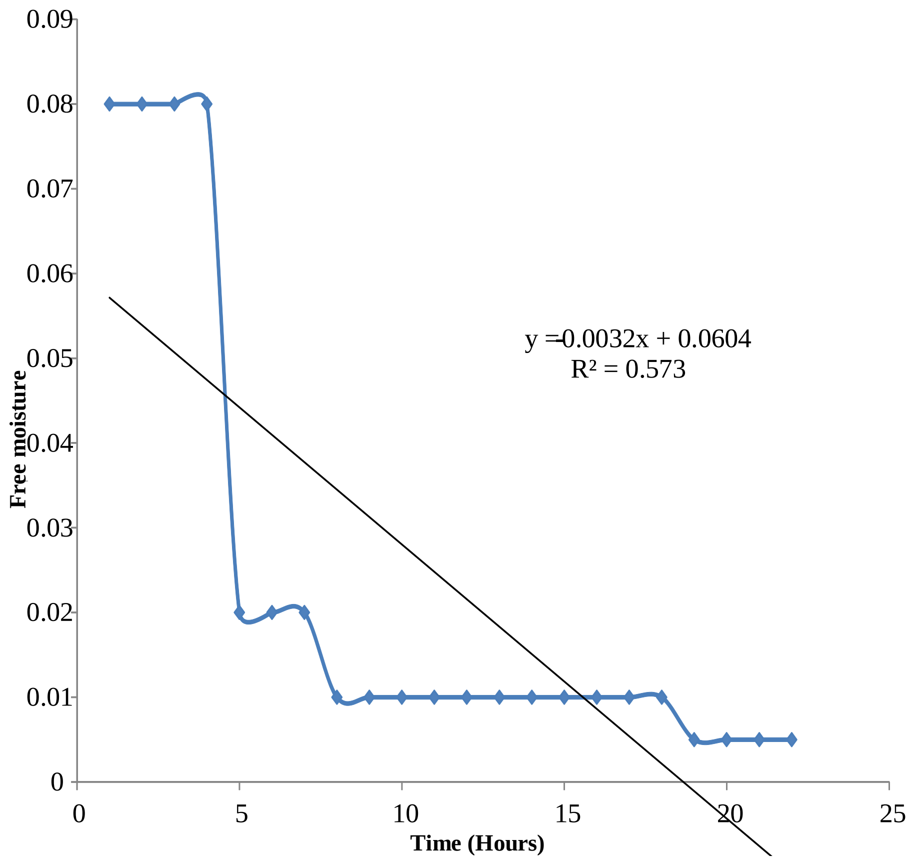

Figure 3. Solar drying of Utazi leaf.

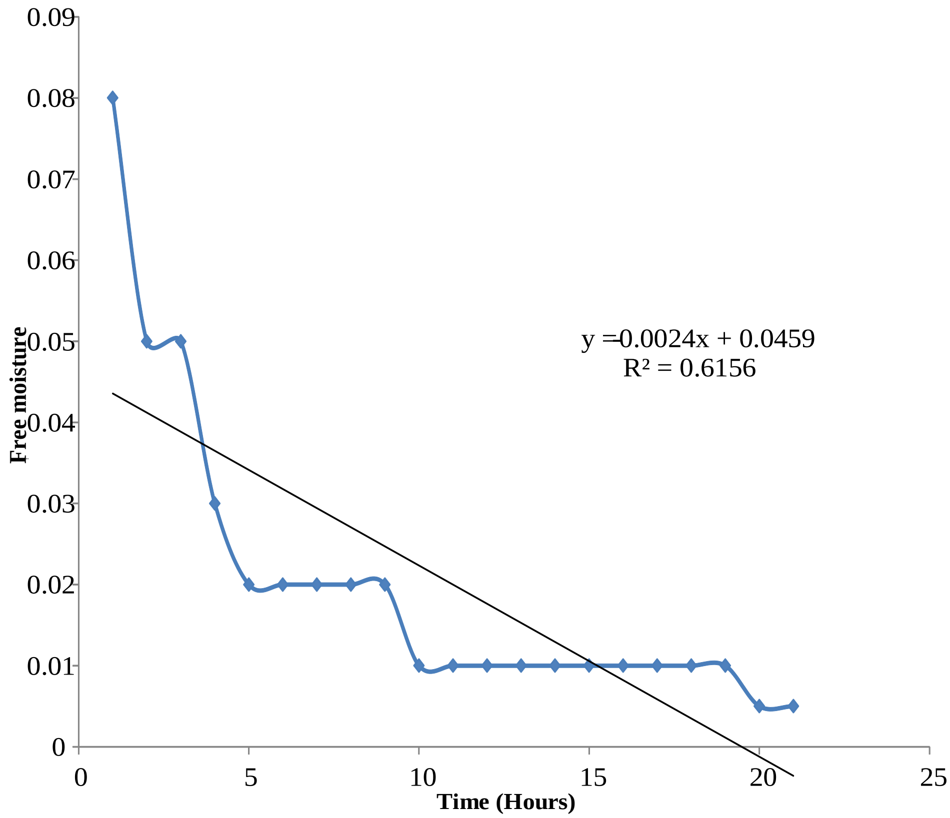

Figure 4. Open-air drying for Nchuanwu leaf.

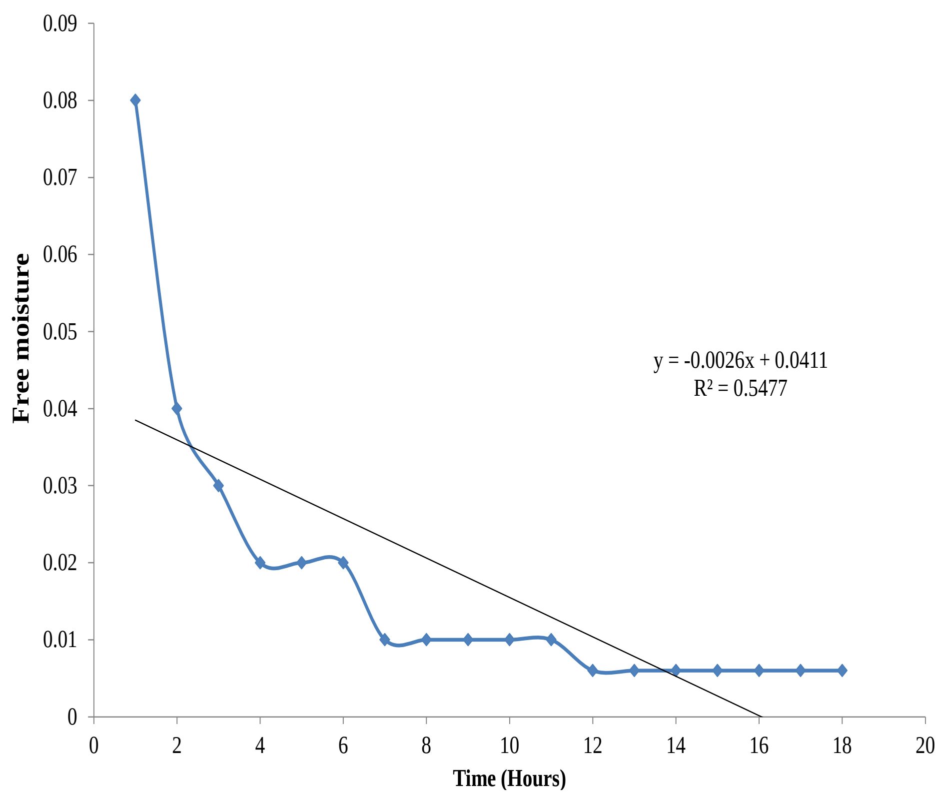

Figure 5. Solar drying for Utazi.

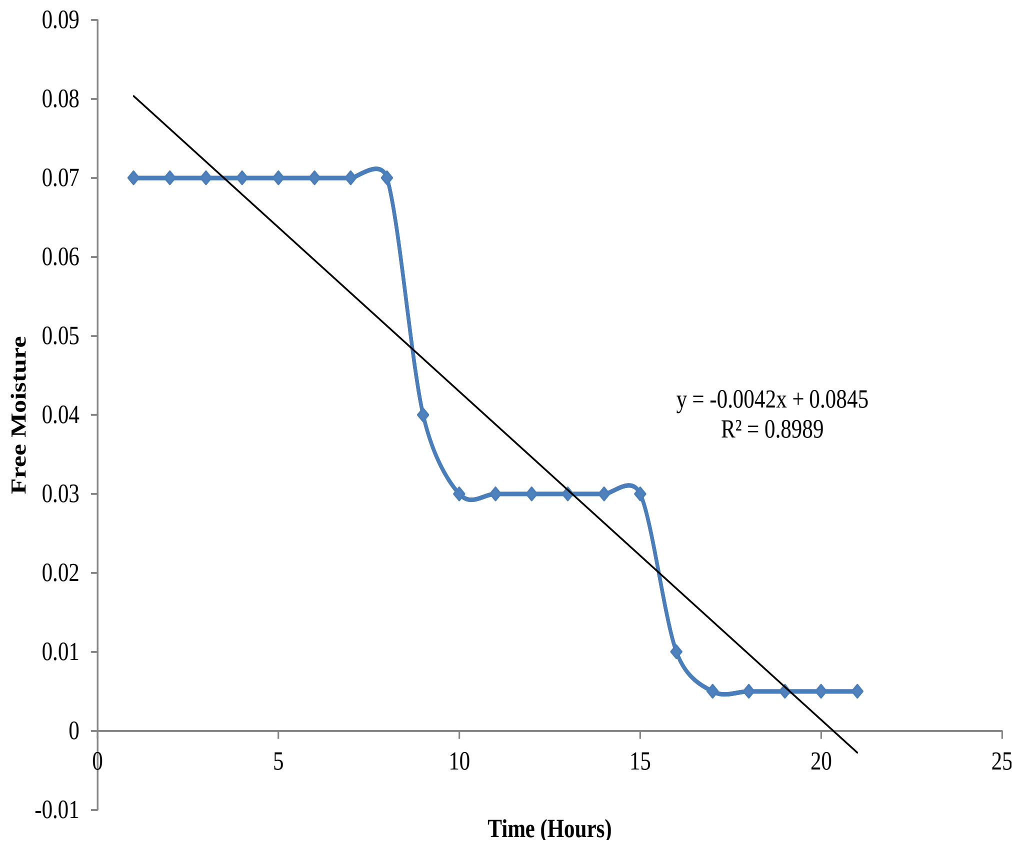

Figure 6. Open-air sun drying for Utazi.

Table 1. Proximate composition (%)* of fresh and dry samples.

Moisture	**Fresh (mean)**	**Dry (mean)**	**t-value**	**p-value**
Utazi	72.16	13.82	7145.162	0.0000
Nchuanwu leaf	71.86	11.97	4639.059	0.0000
Protein (%)				
Utazi leaf	0.66	3.10	0.6287.840	0.0000
Nchuanwu leaf	0.46	2.20	7.136	0.0000
Ash (%)				
Utazi leaf	10.97	14.68	453.156	0.0000
Nchuanwu leaf	10.86	16.61	16.325	0.0000
Fat (%)				
Utazi leaf	0.30	0.42	944.278	0.0000
Nchuanwu leaf	0.26	0.31	31.498	0.0000
Crude fibre (%)				
Utazi leaf	11.50	2.90	164.762	0.0000
Nchuanwu leaf	10.26	3.60	384.377	0.0000
CHO (%)				
Utazi leaf	67.30	35.90	6295.389	0.0000
Nchuanwu leaf	48.48	38.50	2.595	0.0000

CHO: Carbohydrate. *The standard AOAC method was used to determine the proximate values of both the fresh and the dry samples.

Table 2. Mineral composition* of the different samples.

Ascorbic acid (mg/100 g sample)	Fresh (mean)	Dry (mean)	t-value	p-value
Utazi leaf	96.87	23.50	57.124	0.0000
Nchuanwu leaf	28.27	6.30	12.908	0.0020
Iron (mg/100 g sample)				
Utazi leaf	5.10	8.15	4.432	0.0110
Nchuanwu leaf	9.87	4.61	52.169	0.0000
Copper (mg/100 g sample)				
Utazi leaf	2.64	0.10	6.644	0.0030
Nchuanwu leaf	6.31	0.11	13.211	0.0000
Calcium(mg/100 g sample)				
Utazi leaf	41.92	20.85	13.610	0.0000
Nchuanwu leaf	33.83	16.94	38.249	0.0000
Zinc(mg)				
Utazi leaf	0.05	ND	-	-
Nchuanwu leaf	ND	ND		

ND = Not Detected. *mg/100 g for both fresh sample and dry sample.

Table 3. Sensory evaluation of the cooked soups*.

Taste	Treatment 1** (mean±SD)	Treatment 2*** (mean±SD)	Control (mean±SD)
Utazi leaf	5.13±2.391	6.25±2.176	6.50±1.461
Nchuanwu leaf	6.13±1.668	6.81±1.377	6.44±2.308
Texture			
Utazi	4.25±2.082	4.63±2.277	5.63±1.147
Nchuanwu leaf	5.31±1.991	6.38±1.708	6.50±1.673
Flavour			
Utazi leaf	4.94±1.806	5.25±2.176	5.69±1.401
Nchuanwu leaf	5.94±2.081	6.31±1.352	6.38±1.784
Colour			
Utazi leaf	4.50±1.897	5.19±2.562	5.63±1.708
Nchuanwu leaf	6.25±1.693	5.75±2.145	6.50±1.713
General acceptability			
Utazi leaf	4.81±2.536	5.06±2.670	6.13±2.029
Nchuanwu leaf	5.88±2.062	6.31±1.580	7.25±1.291

* These vegetable samples are used for soup preparation;** Statistical treatment for fresh sample
*** Statistical treatment for dry sample.

DISCUSSION

From the free moisture time graphs it is evident that there appeared to be multiple falling rate periods for each sample. However, the first rate period lasted for less than five hours in both drying techniques, an indication that the original assumption of one rate period is quite justifiable (Anyanwu and Okonkwo, 2008; Dissa et al., 2011). The above information is critical to peasant farmers and industrial applications because specified levels of moisture content could be linked with a specified time in the process equation.

CONCLUSION AND RECOMMENDATIONS

The study revealed the quantification of the drying rate constants, K, the drying efficiency and the nutrients and sensory qualities of the vegetable samples dried under the two drying conditions. The free-moisture versus time graphs showed that the drying took place at the falling rate period. Solar dryer was more efficient and has potential to give higher product quality than the open-air sun drying. However, solar dryer would be more costly than the open-air sun drying technique but when quality and safety are considered, the former should be better in the drying of vegetables. Also, the study showed that drying resulted in improved nutrients and sensory qualities of the samples. The process if adopted would ensure steady availability of these vegetables all the year round.

Conflict of Interest

The authors have not declared any conflict of interest.

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REFERENCES

AOAC (1995). Association of Analytical Chemists. Official Methods of Analysis, 15th edn. Washington, D.C

Anyanwu CN, Okonkwo WI (2008). Experimental determination of the drying rate of chilly yellow pepper (Capsicum anuum). Nig. J. Solar Energy 19(1):18-24.

Cochran WG, Cox GM (1992). Experimental Designs, 2nd edn. New York: Wiley.

Coulson JM, Richardson JF (1977). Chemical Engineering, vol. 1 3rd Ed, A. Wheaton & Co, Exeter, GB.

Dissa AO, Desmorieux H, Bathiebo J, Koulidiati J (2011). A comparative study of direct and indirect solar drying of mango. Global J. Pure Appl. Sci. 17(3):273-294.

Doymaz I (2004). Drying kinetics of white mulberry. J. Food Eng. 74:341-346. http://dx.doi.org/10.1016/S0260-8774(03)00138-9

Ekechukwu OV (1989). Performances of a large integral type passive solar energy dryer for rural application. Natl. Centre Energy Res. Dev. J. 1:173-176.

Eze JI, Chibuzor EE (2008). Evaluation of the drying efficiency of solar cabinet dryer using okra and tomato. Nig. J. Solar Energy 19(1):25-33.

Karathanos VT, Belessiotis VG (1997). Sun and artificial air drying kinetics of some agricultural products. J. Food Eng. 31: 35- 46. http://dx.doi.org/10.1016/S0260-8774(96)00050-7

Lashsasni S, Kouhila M, Mahrouz M, Jaouhari JT(2004). Drying kinetics of prickly pear fruit (Opuntia ficus indica). J. Food Eng. 61(2):173-179. http://dx.doi.org/10.1016/S0260-8774(03)00084-0

Mwithiga G, Olwal JO (2005). The drying kinetics of kale (Brassica oleracea) in a convective hot air dryer. J. Food Eng. 71:373-378. http://dx.doi.org/10.1016/j.jfoodeng.2004.10.041

Onoja US, Iroegbu JC, Eze JI (2012). A comparative study of the drying rate constant, drying efficiency, nutrients and sensory qualities of dried vegetables using solar dryer and open-air sun drying methods. Global J. Pure Appl. Sci. 18(3-4):125-133.

Oparaku NF (2008). Development and performance evaluation of medium-scale solar fish dryer. Nig. J. Solar Energy 19-1:34-39.

Sacilic K, Elicin AK, Unal G (2006). Drying kinetics of Uryani plum in a convective hot air dryer. J. Food Eng. 76:362-388. http://dx.doi.org/10.1016/j.jfoodeng.2005.05.031

Scanlin D, Renner M, Domermuth D, Moody H (1997). The design, construction and use of an indirect through-pass solar food dryer. Home Power 57:62-72.

Tongrul IT, Pehlivan D (2004). Modeling of thin layer drying kinetics of some fruits uder open-air sun drying process. J. Food Eng. 65(3):413-425. http://dx.doi.org/10.1016/j.jfoodeng.2004.02.001

Uretir G, Ozilgen M, Katnas S (1996). Effects of velocity and temperature of air on the drying rate constant of apple cubes. J. Food Eng. 30:339-350. http://dx.doi.org/10.1016/S0260-8774(96)00056-8

Whitefield D (2002). Solar Dryer Systems and the internet: Important Resources to Improve Food Preparation. Conference Paper, International Conference on Solar Cooking, Kimberley, South Africa.

Yaldiz O, Ertekyn C (2001). Thin layer solar drying of some different vegetables. Drying Technol. 19(3&4):583-597. http://dx.doi.org/10.1081/DRT-100103936

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