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Assoc. Prof. Eng. KISS Imre, PhD.
UNIVERSITY POLITEHNICA TIMISOARA,
FACULTY OF ENGINEERING HUNEDOARA

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The ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XV [2022], Fascicule 3 [July – September] includes original papers submitted to the Editorial Board, directly by authors or by the regional collaborators of the Journal.

Also, the ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XV [2022], Fascicule 3 [July – September], includes scientific papers presented in the sections of:

- International Symposium (Agricultural and Mechanical Engineering) – ISB–INMA TEH' 2021, organized by Politehnica University of Bucharest – Faculty of Biotechnical Systems Engineering (ISB), National Institute of Research–Development for Machines and Installations Designed to Agriculture and Food Industry (INMA Bucharest), Romanian Agricultural Mechanical Engineers Society (SIMAR), National Research & Development Institute for Food Bioresources (IBA Bucharest), National Institute for Research and Development in Environmental Protection (INCDPM), Research–Development Institute for Plant Protection (ICDPP), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and "Food for Life Technological Platform", in Bucharest, ROMANIA, between 31 October – 1 November, 2021. The current identification numbers of the selected papers are the **#5, #6, #10, #13, #19** and **#20**, according to the present contents list.

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[1.] Mihaela OSACI, [1.] Corina Daniela CUNȚAN, [1.] Ioan BACIU

LUA PROGRAMMING FOR FEMM APPLICATIONS (FINIT ELEMENT METHOD MAGNETICS)

[1.] University Politehnica Timişoara, Faculty of Engineering of Hunedoara, Electrical Engineering and Industrial Informatics Department, Hunedoara, ROMANIA

Abstract: The paper presents, through case studies, the importance of Lua script programming for electromagnetic field applications numerically solved with FEMM (Finite Element Method Magnetics). Going over the simplicity of the language and the "open source" character, Lua can solve a number of aspects that FEMM cannot offer through its visual tools in the preprocessor and postprocessor, among which: interactive modification of the values of some parameters, interactive modification of the geometry of the problem, facilities for saving graphic results, ... It gets, by Lua programming, to the point where no graphics tool of the FEMM suite is required.
Keywords: finite element method, scripting language, Finite Element Method Magnetics, Lua programming, electromagnetic field

INTRODUCTION

Electromagnetic field theory shows that very few problems of electromagnetism have analytical solutions, that is, solutions in the form of mathematical functions describing the behaviour of the electromagnetic field in a region from space to time and space [1], [2], [3]. That is why in most problems involving the design of electromagnetic devices, numerical methods are used. Of the numerical methods existing in the literature, the finite element method is one of the most used for the numerical calculation of the electromagnetic field at industrial frequencies and of the electrostatic, magnetostatic, or stationary magnetic field [4].

Currently, there is available a set of graphical interface applications for electromagnetic problems based on the finite element method, of which are mentioned here: Ansys, Comsol Multiphysics, FEMM (Finite Element Method Magnetics) [5], [6], [7].

Finite Element Method Magnetics (FEMM) is an open source software application for solving electromagnetic problems based on the finite element method [7], [8]. This application can be easily used to numerically solve electrostatic problems, magneto-static problems, and stationary magnetic, respectively low frequency magnetic problems. FEMM is a product much used both in science and engineering and in academia [9], [10], [11], [12].

A scripting language is a runtime programming language that automates the execution of tasks that are typically performed by a human operator. Tasks that can be automated by scripting can be related to software applications, text editors, web pages, operating system shells, embedded systems and computer games [13].

Lua is a powerful scripting language, easy to use, efficient and built-in. It supports procedural programming, object-oriented programming, functional programming, data-driven programming and data description. Lua combines simple procedural syntax with powerful data description structures [14].

In addition to the general instructions, the Lua language presents a series of FEMM application-specific instructions that can achieve a series of dynamic effects at both the pre-processor and postprocessor levels. This paper presents a series of case studies that aim to highlight the importance of scripting in solving FEMM electromagnetic field problems [8].

THE IMPORTANCE OF LUA SCRIPT PROGRAMMING FOR ELECTROMAGNETIC FIELD APPLICATIONS SOLVED NUMERICALLY WITH FEMM THROUGH CASE STUDIES

FEMM with the help of its tools can numerically solve an electromagnetic field problem for a given geometry. Here we can come up with an example, presented as a tutorial also in the specialized literature [15], the calculation of the electromagnetic force of interaction that is exerted on an iron ball located at a distance given by a cylindrical coil without magnetic core travelled by constant current (figure 1).

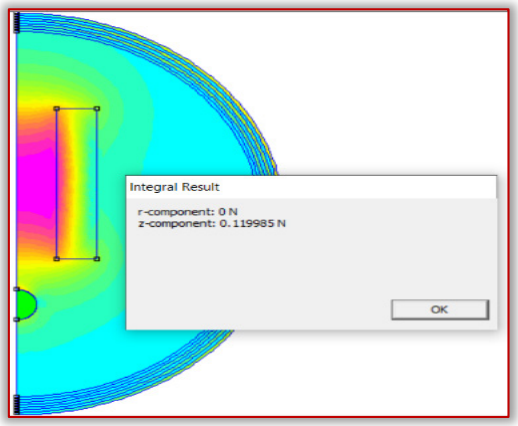

Figure 1. Result in FEMM postprocessor for the electromagnetic force of attraction between an iron ball and a coil travelled by constant current

If one were to calculate the electromagnetic force for several positions of the iron ball, classically, for each position of interest of the ball, the geometry of the ball would have to be reconstructed in the postprocessor and perform the classical operations of obtaining the solution, then the solution, respectively the value of the force and the coordinate of the position of the ball should be manually noted somewhere. This modality is expensive, time-consuming, and can also generate errors when transcribing the solution. The calculation of the electromagnetic force exerted on the ball, for different positions of the ball, can be automated by a Lua script.

In order to program Lua, the iron ball's belonging to a group is set in the pre-processor, for example, the group with the number 1 (figure 2). A group number is a label that can be applied to different lines, arcs, and block labels in a geometry. The advantage of introducing elements of the model into a group is that then all the members of the group can be selected either with a single click in the user interface, or with a single command in a Lua script.

As facilities the script shows the console Lua, by showconsole(), instruction so that the results are visible. The full geometry of the problem is loaded into FEMM and then saved with a different file name, temporarily, so that the original geometry is not overwritten later.

```
mydir="./"
open(mydir .. "bobinaLua.fem")
mi_saveas(mydir .. "tempbobinaLua.fem")
mi_seteditmode("group")
```

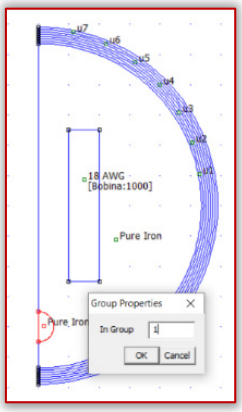

Figure 2. Labelling the moving part of the geometry

Next is the group editing mode through mi seteditmode("group"). The script will then evaluate the geometry of the ball in a number of different positions, displaying the force from each position on the Lua console. To assess the force, all elements associated with the block labels in Group 1 (which we use to represent parts of the moving ball) are selected using the command mo groupselectblock(1). The force is calculated by invoking fz=mo_blockintegral(19), which returns the directed component z of the force calculated from the tensor of voltages. The ball is moved by the instruction mi_movetranslate(0,0.1) by prior selection of the corresponding group by mi_selectgroup(1)

```
for n=0,15 do
  mi_analyze()
  mi_loadsolution()
  mo_groupselectblock(1)
  fz=mo_blockintegral(19)
  print((15-n)/10,fz)
  if (n<15) then
    mi_selectgroup(1)
    mi_movetranslate(0,0.1)
  end
end
```

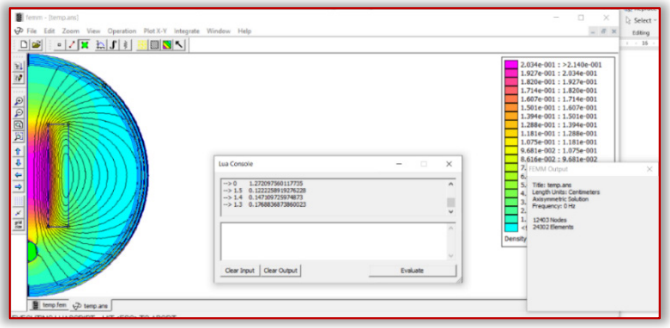

Figure 3. Results in the Lua console

The Lua script can be written in a text file that can be saved with the "take" extension and can be launched into execution from femm environment, File menu, with open lua script command (Figure 3).

If you want to keep the geometries from the postprocessor in each of the successive positions of the ball, this can be done by saving a screenshot in the graphic file with the bmp extension in the current folder, for example. For this, after the geometry change sequence, the following lines of code can be inserted:

```
fisier=tostring(n)
mo_savebitmap(mydir .. fisier..".bmp")
```

Results are shown in Figure 4. Figure 5 there can be viewed some of the 15 graphic situations generated for the calculation of the electromagnetic force.

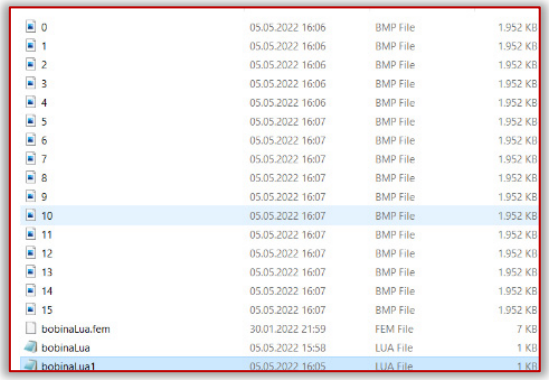

Figure 4. Created graphic files

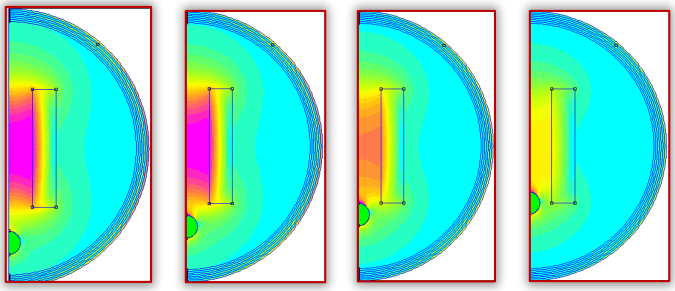

Figure 5. Generated graphic situations

A second case study will highlight the possibility of automatic modification of some parameters of the problem through the script take. The problem highlights the skin effect in a massive conductor driven by alternating current of a given frequency (figure 6).

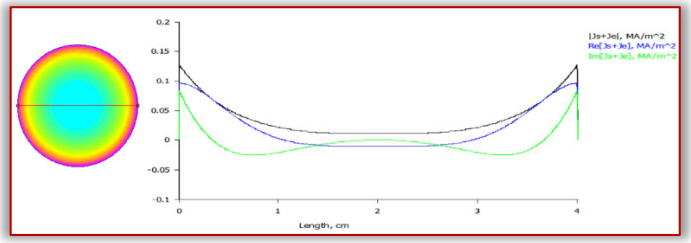

Figure 6. FEMM study of the film effect in massive conductors

If the study of the abutment of current density lines toward the periphery of the massive conductor at different frequencies of current passing through the conductor, would be wanted, you would have to change the frequency in the pre-processor in problem definition (figure 7), and do, in order, a series of operations as the launch in execution of the solver, drawing in the post-processor a contour line along the diameter of the conductor and constructing the current density graph according to length.

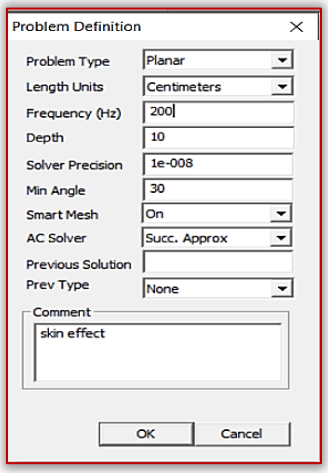

Figure 7. Manual frequency change in the FEMM pre-processor

With Lua code, written in a notepad text file with the extension Lua, saved in the current directory where the FEMM file was saved, it can automate these procedures. Basically one opens the console take with the statement showconsole(), then one opens file in which we defined the FEMM problem and copy this file to a temporary file in which the changes will be made automatically.

```
mydir="./"
open(mydir .. "skin.fem")
mi_saveas(mydir .. "skintemp.fem")
```

In a for cycle with the frequency f meter varying from 200 to 1000 Hz, the frequency changes in the definition of the problem with mi_prodef(f), the mi_analyze() solver is executed, and the solution is loaded into the post-processor with mi_loadsolution(). In the post processor, the edit mode is set on contour with mo_setedmode("contour"), the contour is drawn with mo_addcontour(-2,0) and mo_addcontour(2,0), respectively. To display the results, the frequency value is taken into a variable, it is converted to string with file=tostring(f), then with mo_makeplot(8,200, mydir .. file..".bmp") the current density graph is made in a bmp file with the name frequency (figure 8) value for f=200,1000,100 do

```
mi_probdef(f)
mi_analyze()
mi_loadsolution()
mo_seteditmode("contour")
mo_addcontour(-2,0)
mo_addcontour(2,0)
fisier=tostring(f)
mo_makeplot(8,200, mydir .. fisier..".bmp")
end
```

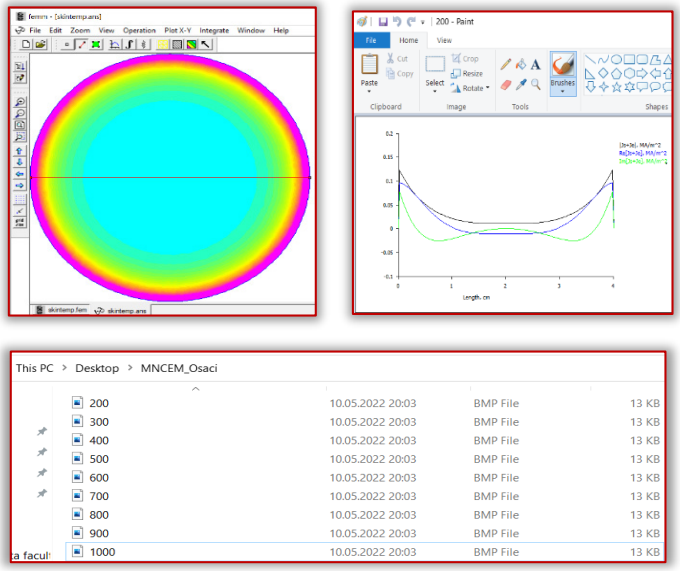

Figure 8. Results obtained with Lua script

The third case study shows how all visual actions performed in FEMM to obtain a numerical result for a problem are done using a Lua script. The problem is the distribution of the electrostatic field between the fittings of a cylindrical capacitor. Through the la console, constructive parameters of the capacitor are introduced, namely: The radius of the outer armature, the radius of the inner armature and the length of the capacitor (figure 9). A fee file is then opened in the electrostatic pre-processor which is named according to the constructive parameters.

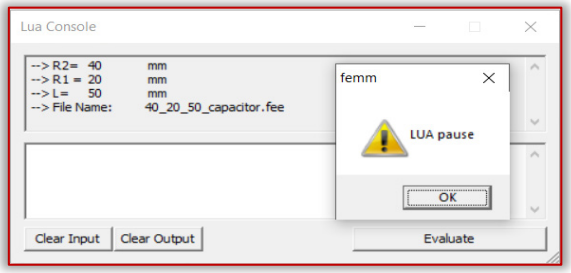

Figure 9. Introduction of the capacitor parameters through the Lua console

Also through the console, the name of the material between the fittings and the electrical permittivity of the material (figure 10) is introduced.

After which from the Lua code the planar geometry of the capacitor is achieved, the conductors for the fittings are defined and the fittings are attached, the material between the fittings is attached to the geometry, the mesh is generated, the solver is launched in execution, the solution is loaded into the post-processor and the result is obtained,

that is, the distribution of the electrostatic field between the capacitor fittings in the colour code-figure 11 and figure 12.

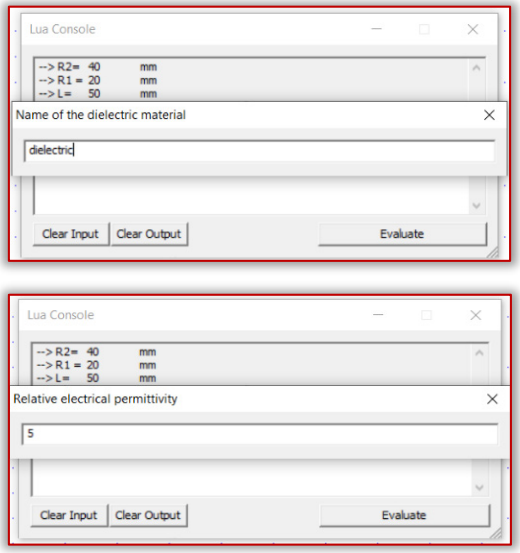

Figure 10. Introduction of the dielectric parameters through the Lua console

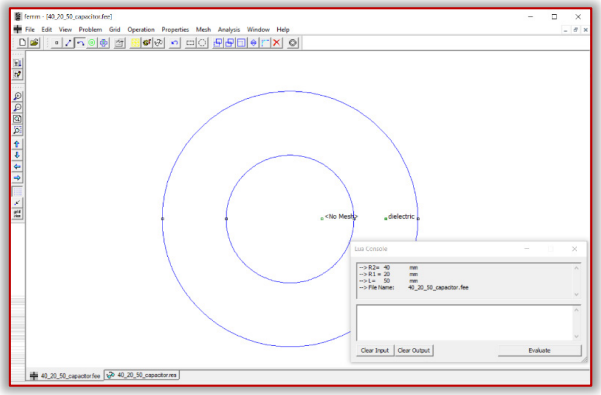

Figure 11. Fee file in electrostatic pre-processor

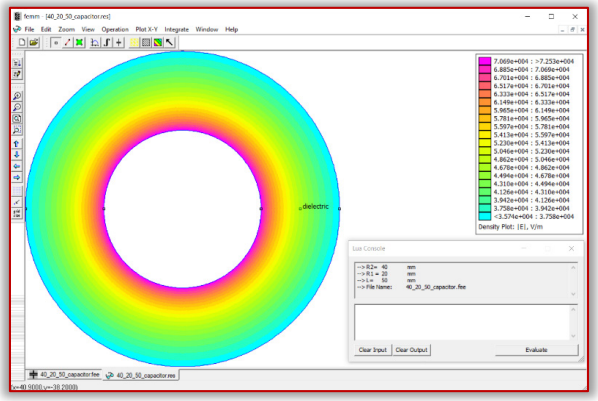

Figure 12. The res file with the simulation result in the electrostatic post-processor

CONCLUSIONS

The paper presents, through case studies, the utility of the Scriptural programming of the Lua for the dynamic implementation of some facilities that cannot be achieved through the implementation of visual FEMM. The first case study presents an automation of a calculation on a dynamic geometry, the second case study presents the possibility of changing the parameters of a problem dynamically, and the third case study presents the implementation of an electrostatic FEMM problem by the AI code. It is noted the ease of using the language, the fact that from few lines of code, both numerical results and very consistent graphic results are obtained, and last but not least the possibility of dynamic implementation of behaviours that, classically, only with FEMM tools could not be achieved.

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[1.]Ervin LUMNITZER, [1.]Elena JURGOVSKÁ

METHODOLOGY FOR THE ASSESSMENT OF ELECTROMAGNETIC FIELDS GENERATED BY MOBILE BASE STATIONS

[1.]Technical University of Košice, Faculty of Mechanical Engineering, Department of Environmental Engineering, Košice, SLOVAKIA

Abstract: One of the most common sources of electromagnetic fields (EMF) in the environment, which is most visible to the public, is the base stations of mobile operators. This contribution shall be devoted to the development of a methodology for the assessment of EMFs generated by mobile base stations. In order to address this issue, an experiment was carried out to assess the electromagnetic fields in the selected industrial site. In the experiment, measurements were made of the intensity of electromagnetic fields at the selected measuring points in the various operating modes of the V5 base station — on and off. Subsequently, measurements were made of the intensity of the electromagnetic fields during the operation of the mobile MBTS base station, which was temporarily operated on the site under consideration. In the various operations of the base station, the measured intensities of the electromagnetic field were manifested differently depending on the location of the measurement. The results of the experiment suggest that consideration should be given to the appropriateness of the EMF evaluation methodology, which favors the evaluation of a particular resource rather than the entire site.

Keywords: Methodology, electromagnetic field, the base station of mobile operation, experimental measurement

INTRODUCTION

In recent decades, there have been rapid developments in telecommunications and information technology, which bring with them increasing levels of electromagnetic fields in the environment. Despite the fact that, since the 1980s, increased worldwide attention has been paid to electromagnetic fields, their measurement, monitoring, and assessment, it has been necessary to make further progress in the methodological area, which mainly concerns the search for new, modern approaches to the objectification of EMF specific sources [1]. Exposure to electromagnetic fields from mobile base stations shall be controlled in accordance with the legislation currently in force. From the point of view of the safety of the population, mobile operators must carry out individual health measurements whenever technology changes at base stations.

In an article by Boo, SF et al. [2], authors conducted an experiment comparing the radiated power levels of base stations with the ICNIRP safety guidelines. The measured EMF levels were lower than the ICNIRP exposure limits. Similarly, in [3], measurements of exposure to electric, magnetic, or electromagnetic fields (EMF) in households were performed. In the article, they reported that all measurement results were well below the International Commission on Non–Ionizing Radiation Protection (ICNIRP) guidelines. Yuan et al. [4] monitored the environment around base stations. They found that the requirements of electromagnetic limits for environmental control were met at all monitoring sites in urban areas.

The contribution describes an experiment in which we carried out measurements of the intensity of electromagnetic fields at a selected location under different operation modes of the base stations. This is the case where one base station has been canceled and replaced by another base station situated elsewhere. Subsequently, an analysis of the strength of the electromagnetic field was carried out at various measuring points. The results of the frequency selective measurement are shown in the frequency spectrum tables and graphs. The result of the measurements is also the cumulative electromagnetic field intensity values, which can be compared to the action, and legislative values.

EXPERIMENT MEASUREMENT OF ELECTROMAGNETIC FIELDS

An experiment to assess changes in the intensity of electromagnetic fields generated by mobile base stations was carried out by measurements at a selected location. We chose this area because of the large number of base stations present in the area. This site is located on the Južná trieda in Košice, Slovak Republic. There are currently 10 mobile operator base stations on the site and a mobile base station is acting as a temporary replacement. Several operators operating in Slovakia have base stations located in the designated area. In Figure 1, there is the location of the base stations at the selected site as well as the azimuth of the antenna radiation.

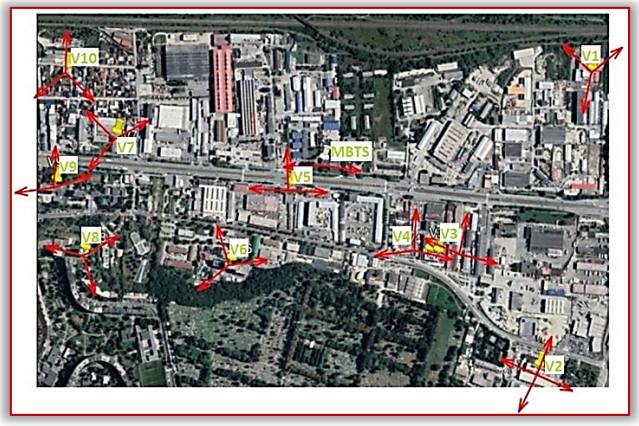

Figure 1. Site assessed with EMF radiation sources

The V5 base station was significant for our experiment, given that we changed the mode of its operation when we measured it. It's on the roof of the building. The antennas are located at 17m and 20m above ground in 3 sectors with the azimuth of 75°, 170°, and 350°. The base station shall use the following frequency bands 900 MHz, 1800 MHz, 2100 MHz, and 2600 MHz. The antenna types at this point are ARIA3415, APXVERR26–C for 900 MHz, 1800 MHz, 2100 MHz, and APXVLL13N–C–na20 for the 2600 MHz frequency band.

The MBTS mobile base station is located next to an existing building at 68 Južná trieda Street. The mobile base station is operated as a dual–sector with ADU4518R9v06 antennas at a height of 15 m and azimuths of 175° and 345°. MBTS uses all frequency bands, i.e. 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, and 2600 MHz.

SELECTION OF MEASUREMENT SITES

In order to assess the impact of the EMF on mobile base stations, we have identified at the selected site 10 measuring points labeled M1–M10. We have focused on the area in which the mobile base station of the mobile operator will be located as a replacement for the V5 base station that has been shut down. In Figure 2, there is the location of the measuring points and their identification by number as well as the V5 base station and its replacement temporary MBTS together with the direction of the antenna radiation.

Figure 2. Location of measurement sites

The measurements have been made at each measuring point for the different modes of operation of the EMF source. The first round of measurements was carried out during the continuous operation of base station V5. We then shut down this source of the electromagnetic field and repeated the measurements. After the mobile base station has been activated and the V5 base station has been completely shut down, we have performed the measurement a third time. Measurements were performed at each measurement site using a Narda SRM–3006 measuring instrument consisting of a spectrum analyzer and a probe for measuring the electric field component. The measuring instrument was placed on a tripod at a height of 1.5 m. The output of the measurements is the frequency spectrum, cumulative values of the electromagnetic spectrum intensity, and the maximum EMF values for the dominant frequencies at each measurement site during individual measurements. The measurement time was set to six minutes. The measurement was performed in the frequency band of the measurement chain from 420 MHz to 6 GHz. During the measurement, the dynamic measurement range was set on the instrument to 10V/m, RBW – 5MHz, the minimum display frequency F_{min} – 700 MHz, and maximum display frequency F_{max} – 3500 MHz.

EXPERIMENT EVALUATION

In evaluating the data obtained by the experiment, we carried out a spectrum analysis, an analysis of the output data, and an evaluation of the results. Data from individual measurements shall be arranged according to the significance of the EMF evaluation by the instrument. The output of the measurement shall also be frequency spectrum graphs and cumulative EMF intensity values for all measuring points.

In processing the results, we set the interfaces of the individual graphs to a significant segment, F_{min} 750 MHz and F_{max} 3400 MHz. On the graph, you can see significant peaks – peaks that occur at an activity at a specific frequency according to the EMF intensity. The resulting tables show the 10 most significant peak values with the highest EMF intensity for a specific base station.

The evaluation was carried out at each measuring point. In the contribution, we offer selected results from locations where the changes were significant.

— Analysis of measurement results at the measuring point M5

The measuring point of the M5 was placed against the source of the V5 electromagnetic field, where the operational changes took place. The distance of the M5 measuring point from the V5 source building shall be 50 m. In Figure 3, there is a representation of the position of the measuring point M5.

Figure 3. Location of the measuring point M5

With the power off, we assumed that the peak values displayed on the frequency spectrum would be minimal. In Table 1, there are the 10 most significant measured values for the various operating modes at the measurement point M5.

Table 1 Peak values of the measuring point M5

Č.	On V5		Off V5		MBTS	
	Freq. [MHz]	Intensity EMF [mV/m]	Freq. [MHz]	Intensity EMF [mV/m]	Freq. [MHz]	Intensity EMF [mV/m]
1	936	1367	1869	699,7	2657	591,8
2	2664	487,1	2653	604,4	805	543,4
3	1869	453,4	946	507,3	2665	396,4
4	2647	451,9	799	364,8	936	300,4
5	954	373,1	935	345,2	950	296,5
6	2629	331,9	789	294,4	1868	285,7
7	2116	292,2	1854	204	2116	230,3
8	1809	275,2	1809	149,9	2138	225,9
9	793	230,5	1879	123,8	2634	193,9
10	802	209	2149	71,96	798	177,7

The following changes have occurred in the different modes of operation (see Table 1):

- F_{2600} – With the V5 source on, the intensity is 451,9 mV / m; with the V5 source off, it is 604,4 mV / m; with the MBTS in operation, it is 591,8 mV / m,
- F_{1800} – With the V5 source on, the intensity is 453,4 mV / m; with the V5 source off, 699,7 mV / m, with the MBTS operating 285,7 mV / m
- F_{800} – With the V5 source on, the intensity is 209 mV / m; with the V5 source off, 364,8 mV / m; with the MBTS operating, 534,4 mV / m

In Figures 4–6, there are the frequency spectrums at the M5 measurement point for the individual base station operation modes.

Figure 4. Frequency spectrum in measurement point M5 – V5 source on

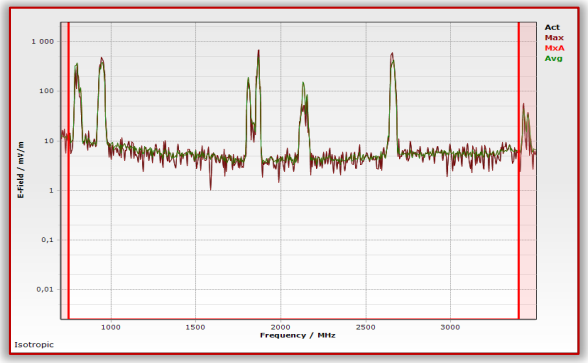

Figure 5. Frequency spectrum in measurement point M5 – V5 source off

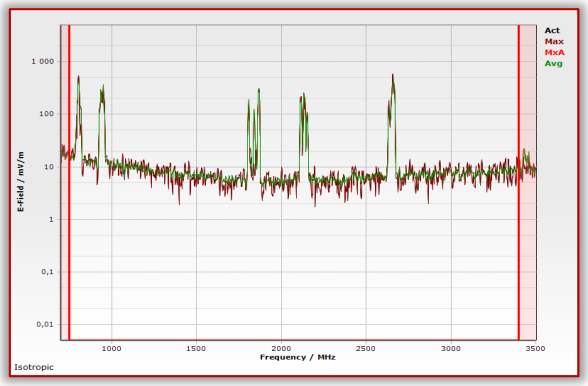

Figure 6. Frequency spectrum in measurement point M5 – MBTS source

The frequency spectrum shown also shows peak values at frequencies that are not generated by the V5 base station. It appears from the technical parameters of the V5 base station that the 800 MHz frequency is not used at the V5 base station, but a significant peak value is displayed in the frequency spectrum in both on and off V5 cases. This implies that the measurement values are also influenced by an unspecified source – probably another base station. Nor has it been confirmed that the V5 base station's measured frequencies will be minimal when switched off (see 1869MHz in tab. 1.).

— Analysis of measurement results at the measuring point M9

The measuring point of the M9 was 105 m from the building where the V5 source is located. In Figures 7 and 8, there is a representation of the frequency spectrums, showing a number of declines in the strength of the electromagnetic field for individual frequencies.

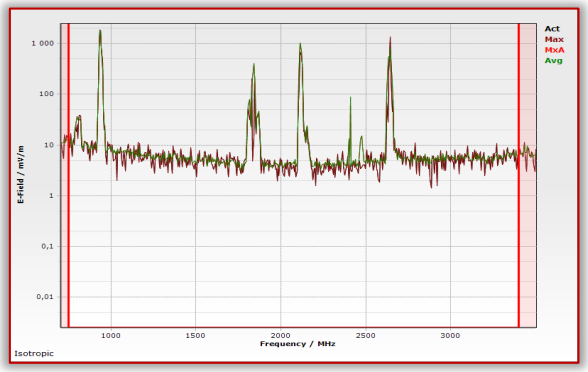

Figure 7. Frequency spectrum in measurement point M95 – V5 source on

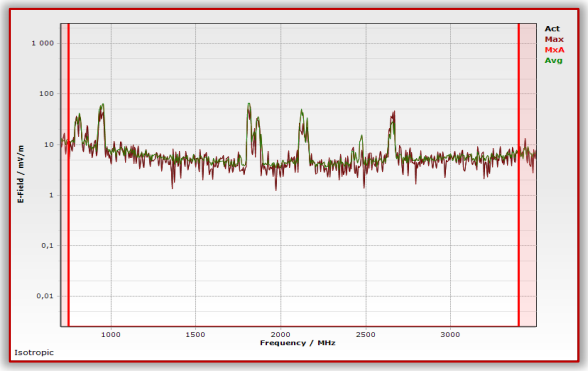

Figure 8. Frequency spectrum in measurement point M9 – V5 source off

In Table 2, the 10 most significant measured values for the various operating modes at the measurement point M9 are given. At 936 MHz with the V5 source on, the strength of the electromagnetic field shall be 2005 mV / m, and, with the V5 source off, the current value shall be 55,19 mV / m, representing a 36–fold decrease (see values marked in tab. 2).

The measurement was carried out in the afternoon, at 4 PM, and the time difference between the on and off measurement was 30 minutes.

Table 2. Peak values of the measuring point M9

Č.	On V5		Off V5		MBTS	
	Freq. [MHz]	Intensity EMF [mV/m]	Freq. [MHz]	Intensity EMF [mV/m]	Freq. [MHz]	Intensity EMF [mV/m]
1	936	2005	1819	55,6	935	305,1
2	2644	1361	939	55,19	803	303,2
3	2114	702,1	1807	52,51	2113	145,9
4	1844	230,2	952	47,85	1838	132,3
5	1829	203,3	2669	46,85	2638	58,52
6	2659	78,28	2658	45,16	1808	52,96
7	2624	67,93	930	44,68	2646	52,12
8	1808	51,78	815	41,32	1865	49,66
9	1818	41,94	2651	39,27	950	49,6
10	1864	41,91	795	37,41	2665	40,39

RESULTS OF THE EVALUATION

From the evaluation of the measurement results, changes in the strength of the electromagnetic field for the individual measuring points are evident for changes in the operation of V5 and its replacement by a mobile base station. This decrease can be seen at all measurement points even at cumulative values. In Table 3, cumulative values for individual measuring points in different operating modes are given.

Table 3. Cumulative values for M1–M10

Measuring point	M1	M2	M3	M4	M5
V5 source on [mV/m]	778,0	252,3	1043	632,0	1631
V5 source off [mV/m]	485,7	169,2	401,9	392,2	1296
MBTS [mV/m]	756,6	397,5	599,0	1043	1292
Measuring point	M6	M7	M8	M9	M10
V5 source on [mV/m]	1174	237,3	486,0	2373	416,0
V5 source off [mV/m]	529,0	148,6	164,1	168,3	369,7
MBTS [mV/m]	773,7	257,8	270,2	555,2	884,9

For example, at the M5 measurement point, the changes in the cumulative values of the electromagnetic field intensity are insignificant, namely 1631 mV / m with the source switched on, 1296 mV / m with the field switched off and the MBTS 1292 mV / m started. At the M9 measuring point, which is also close to the source, during continuous operation, the electromagnetic field intensity value is 2373 mV / m, when switched off, the intensity drops to 168,3 mV / m and, after starting its MBTS replacement, the intensity value rises to 555,2 mV / m.

Mobile operators at the site under assessment operate in the frequency range 800–2600 MHz, which according to the current legislation in force in the Slovak Republic corresponds to the exposure action values for electromagnetic fields of 39 000–61 000 mV / m.

CONCLUSION

Before the experiment, we assumed that the EMP intensity values with the V5 source switched off would be minimal. This assumption has not been confirmed at the measurement point M5. Although the measurement with the V5 base station switched off and on was carried out in a range of about 2 hours, they appeared in the peak spectrum at frequencies that were not considered in the evaluation. At some measuring points e.g. M9 has been shown to decrease the strength of the electromagnetic field several times at individual frequencies compared to the switched–on source. The results of the experiment suggest that consideration should be given to the appropriateness of an EMF evaluation methodology that prioritizes the evaluation of a particular resource rather than the entire site.

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[1.]Miklós SZABÓ, [1.]Zoltán András NAGY, [1.]Tamás HARTVÁNYI

RANDOM ALLOCATION EFFECT ON STORAGE PERFORMANCE

[1.]Széchenyi István University, Győr, HUNGARY

Abstract: Todays not the products race with products, but supply–chains with supply–chains, also every chain is so strong as the weakest part of it. It is essential to show high–performance on market, not just in production, but in logistic process too. A compact rack–system has one of the best area utilization, but it is afraid of less dynamic capacity. The authors started find a solution, how to utilize area for logistic process next to fast material handling. In this paper we publish a simulation that shows out the effect of random allocation on storage performance in a compact rack–system that opens new ways for research.
Keywords: Storage Location Assaignment Problem (SLAP), simulation, compact rack–system

INTRODUCTION

The inventories have two main criteria: static– and dynamic capacity. Static capacity defines the amount of materials could be hold at the same time, dynamic capacity defines the amount of materials could be handled in time–period. Most cases companies use conventional pallet rack system that seems to be the most effective in dynamic capacity, because every pallet is available without moving other pallets, but many times inventories has limited area to use and high amount of materials to handle. In that reason companies have to use other rack systems that are more effective in area utility.

According to Pareto thesis most of the handled materials came from a few Stock Keeping Units (SKUs), while the other small part of materials is many. Because of that the compact rack–system is more logic choice than the conventional one in aspect of SKUs.

We think that compact rack–system can be dynamic too. With compact rack systems less travel–distance has to be done. The question is how to minimize the material–handling. In this paper we make a case study simulation to determine how to set up a warehouse in this situation and what can be reached by that way.

We have two options, how to influence the material–handling performance, first we can say how to allocate materials in a warehouse. By other words: the required time for a list of tasks is depends on, how the warehouse was look like, when the work was started. The second method is to say, what to do, the incoming materials where should be placed and which one should be given out first.

In this paper we present simulations of the warehouse behavior for random allocations compared to the scientific ABC organized solution. The second method will be covered in other time.

LITERATURE REVIEW

Before the simulations we have to pay attention for state of art, because the Storage Location Assignment Problem (SLAP) is an NP–hard problem and researched by many others. Juan José Rojas Reyes, Elyn Lizeth Solano–Charris and Jairo Rafael Montoya–Torres collected 71 representative papers published in the theme between 2005 and 2017 [6].

The problem is often inspected with Genetic Algorithm (GA), for example it is discussed end enveloped by Changkyu Park & Junyong Seo in [11] and [12] or Jing Xie, Yi Mei, Andreas T. Ernst, Xiaodong Li & Andy Song in [7] and [8]. GA makes generally many computations and last long time. In our simulation it is solved much faster aware of could be less effective. Our research could be a good base for GA computations too.

Other approaches collected by Behnam Bahrami, Hemen Piri & El–Houssaine Aghezzaf in [3]. Problem could be solved by classifying the stored materials, that is presented by Ren–Qian Zhang, Meng Wang & XingPan in [5] or R.Micale, C. M. La Fata, G. La Scalia in [4]. In our research ABC analysis is compared to total random allocations.

Our results could be utilized not just in the modelled warehouse, but in many other field where compacted storage systems are preferred, for example in works of Sacramento Quintanilla, Ángeles Pérez, Francisco Ballestín & Pilar Lino [9] or in maritime terminals as shown in works of Xiaoyuan Hu, Chengji Lianga, Daofang Chang & Yue Zhang [2] or Lu Chen & Zhiqiang Lu [10].

SIMULATIONS

— System Description

To solve SLAP we have planned many simulations, they help choose between the solutions. In this paper we represent the first simulations, in what we created with random arrangements for a real situation's reduced model.

Our case study based on data of a factory's raw material inventory. In our model all the materials stored on pallets and use the same size of store location. The FIFO is not a requirement, which could be anywhere, if the materials counted in bound of big series and a new serial means a new material number.

The entrance of the warehouse is in opposite of the exit, so the materials' flow has straight line shape, every material moves across the warehouse to production and none of them comes back, so there is no rest material in our model. In real life the materials have buffing area in production, it is

unnecessary to move them back, they can be hold there for later production, if it is more than the actual serial required. The finished goods stored in other inventory.

We kept the shape of the rack system, which was a drive–in system with 6 pallets deep width and 3 levels height. Materials moved by a forklift and locations are available if there are no other materials in the lane closer to the corridor, but it does not matter on which height it stands. There are two block of racks on the left and right side of the corridor. In each block there are 18 lanes so the maximal static capacity of the model is 648 pallets.

The model inherited the volume ratio of materials in the original inventory. The amount of SKUs is reduced to 100 by selecting every 19th material for simulation, but their volume ratio is almost equal to volume of original inventory's SKU percent volume ratio. That can be seen in Figure 1, how well the Pareto thesis is represented in simulations.

There are 557 materials to starts with. We have to say how to range these items in the warehouse to influence the performance. We don't know what will be, we know only chance what will be a task, so the system is stochastic as randomness of reality, not a deterministic model.

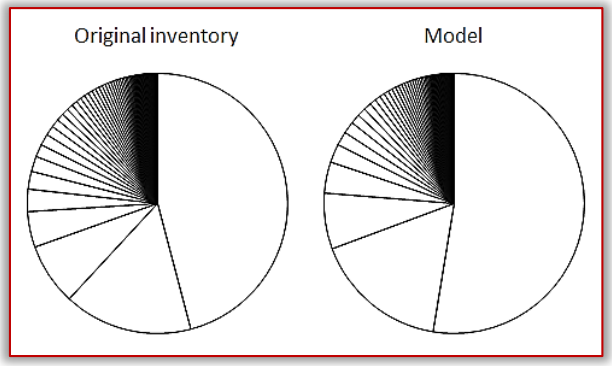

Figure 1. Volume ratio of SKUs

To count the dynamic capacity, we created a table where it is recorded, how many time is needed to move in and out of the rack to or from that exact location. If a needed material is blocked by other materials in the lane, then the others have to be moved on the corridor, then move out the searched one and then move back the others without change the order, just shift a bit deeper. It is not allowed to left an empty location blocked in any lane. The time needed to make a location free is calculated in table too, depending on the location coordinates and the blocking locations before that.

To evaluate the efficiency of storage location assignment we made simulations with 100 task–lists, each list contains 2000 tasks. Every task could be either get in or a give out.

The task lists were build up in aspect of the past and it tries to get the inventory fulfilment about 80% and never ask a material that is not stored in yet. When the task–lists were built, there was higher chance to store in the lower fulfilment and low chance to get something out, and there was lower chance to store in something in higher fulfilment and higher chance to get something out.

We kept the circulate habit of the materials, rate of materials and amount of items should store in and given out, so for example if a material used to come in on 20 pallets, then it generated 20 tasks of the same material to store in followed by each other, before another task were generated.

Each task–list is independent to others, but each were generated by the same chances. The task–lists were recorded to keep it in every simulation, in that case they are comparable.

The exact location is chosen by greedy algorithm: when a unit has to be placed in, the system chooses the shortest way in time to deploy if that is a valid location, and when a unit has to be given out, the system chooses the fastest available unit to give out. There is no restriction between materials and locations every material could be placed on any location.

The value of solutions was calculated with the following formula:

$$v = \frac{\sqrt{\frac{\sum_{i=1}^{n}\left(\sum_{j=1}^{m} t_{ij}\right)^2}{n}}}{m} \quad (1)$$

where v means the value of a simulation, m is the amount of tasks in a task–list, n is the amount of task–lists and t_{ij} is the time required to do the j task in i task–list. With this formula a weighted average is given for time required to do a task. Behind the weighting stands the same theory a behind the average distance to mean value and deviation. If a solution solved the task–lists with the same average time required in another solution, but it has less deviation, than it get a better value. Of course the aim of the simulations is to minimize v value.

— First run

We generated total random arranges to see, how it can impact the performance of warehouse. The first 1000 solutions were ranged from 90.7 to 101.3 as it is shown in Figure 2.

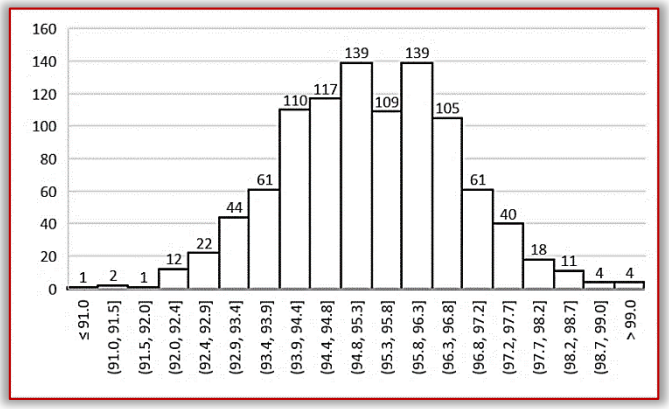

Figure 2. Histogram of simulations by the first 1000 arrangements

The ABC analytic solution was 94.4, so the 26% of random arranges were better than this. We made hundred tusk–lists to avoid getting solutions around one exact situation – that could be easily defined by the given order, we wanted to get an approximately good solution for any stochastic–possible situations. For a similar reason it is important to have many

tasks in every task–lists, and that helps find solutions for long time.

The required time for a task could be less than 30 seconds if it could be done near to the corridor, but if a material is deeply covered and 15 positions have to be empty before it and later move the materials from there back, then it could take almost a half–hour. The question is how many times they will occur.

The average operation–time is changing during the list – it could be seen in Figure 3, where we display it for the best, the worst and the median solution. The ABC analytic solution is indicated with red line.

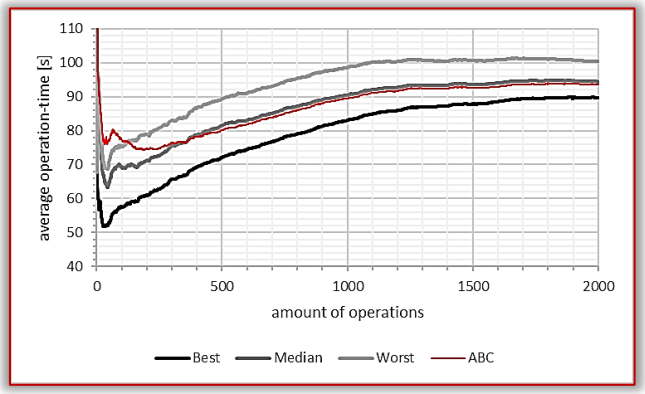

Figure 3. Average operation–time in simulation depending on amount of operations

The first 300–400 tasks' average operation–time is varying a lot, from here to 1100–1600 it is increasing constantly and in the final part it is converging to one value. In the first part they can be judged well, but in the followings every line is going parallel to each other and lastly no big changes are expected, it seems unnecessary to have longer task–lists.

— Validation

To prove the simulations are good to test the effectiveness of arranges after the first thousand simulations we created a new hundred task–lists with 2000 tasks in each as it was written earlier. The simulations' *v* value in the original and the newly generated validating data have to be near to each other. If the result is the same, then the arrange optimization would be independent to task lists, but if the differences are high, then the result is task–list specific.

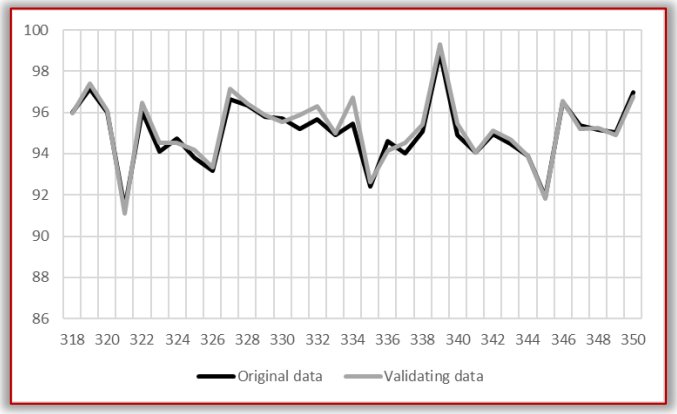

Figure 4. The value of original and validating data around the biggest differences (Case 334)

The new values of the solutions were luckily only 0.32% different from the first run. The biggest difference 1.34% was at the Case 334, as it can be seen between some of the two values are sampled in Figure 4. The vertical axis is for the *v* values and the horizontal axis shows the identification number of cases. The values of the whole 1000 members range are on average 0.20% higher than the original ones.

With this small differences, the method seems to be right, the simulations could be continued for a bigger research with the original task–list.

RESULT OF TEN–THOUSAND SIMULATIONS

After the validation of the method, we continued the simulations to extend the case–numbers to ten–thousand. The mean value changed from 95.32 to 95.30, the best value was reduced from 90.70 to 90.54, but there was no worse than in the first thousand case, so the worst value didn't change from 101.29.

As it was shown in Figure 3 for the first thousand simulations, we present the average operation–time changing during the task–lists by the best, the worst and the median solution in Figure 5 for the extended range.

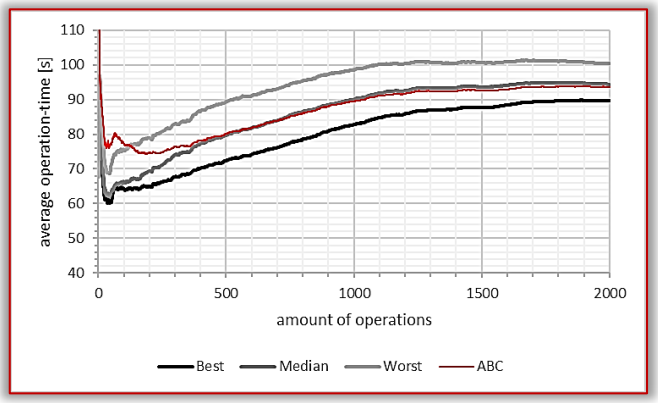

Figure 5. Average operation–time in simulation depending on amount of operations

The three parts are on the same period, the behavior of the lines are also the same, but the best solution comes from much higher value, so it started from a worse position, but the final value becomes better.

The median line goes in the opposite way, it started from a much better first period, but become the same as in case of the first runs, they different only after the 5th digit: the *v* value changed from 95.28212 to 95.28211. These changes make us sure, we had to make all the 2000 tasks in all task–lists.

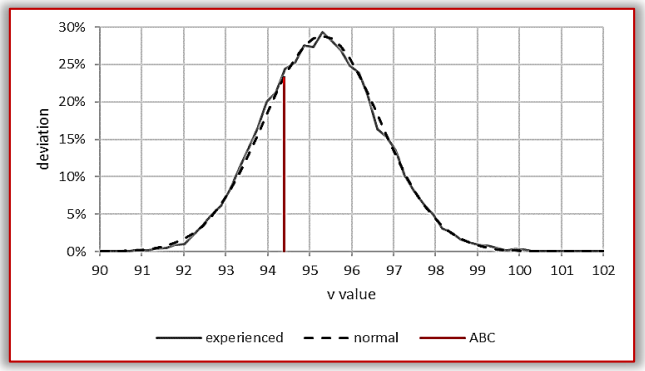

Figure 6. Experienced deviation of simulations' *v*value and normal distribution

The result of the simulations is well described by a normal distribution. According to Kolmogorov–Smirnov test, it has 61% confidence, because the biggest difference between normal and experienced distribution is 0.0090 around 44%. The experienced deviation is indicated with it in Figure 6. A red line shows, where is the ABC analytic solution and all the solutions on left to it are better. The best experienced solution makes it about 4% better.

CONCLUSION AND FUTURE WORK

We presented the Pareto thesis' impact to utility of rack–systems efficiency in warehouses, collected methods and to SLAP, developed a simulation system for an exact problem, to show out, how important is to pay attention on materials arrangements, validated the method and made 10 000 simulations.

We don't think, that our best random arrangement for the problem is good enough, but this experience proved that it is worth to looking for better solutions. The presented simulations could be a good base to start GA population or could be used for a neural net building.

There are many questions that we would like to answer in the future:

- We would like to build a general model, to make simulations with other rack–systems, other shapes and constructions to optimize the area–utility. What shapes is ideal for a situation and what influence it?
- How many racks should be compact and many conventional ones should be used to optimize area–utility? How deep and how high they should be?
- How would impact the result if the temporary storage on the corridor is prohibited?
- What can we reach if the selection in model would be changed from greedy algorithm to something else?
- What we have to do if we can see further for example ten or twenty tasks and not just one?
- How to arrange the inventory if we would have better solutions in short terms?
- When is it worth to make the calculations for a new arrangement and rearrange the warehouse? Could it be done by new dynamic process?

When we answer these questions, then the supply chains could be better served by the warehouses.

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[1.]Ernesto GONZÁLEZ CABRERA, [2.]Roberto Cespón CASTRO, [3.]Norge Isaías COELLO MACHADO, [4.]Elke GLISTAU

PROCEDURE FOR IMPROVEMENT OF THE ADMINISTRATION OF WAREHOUSES IN THE FACTORY RUM CUBAY

[1,2.]Industrial Engineering Department, Universidad Central "Marta Abreu" de Las Villas, (UCLV), CUBA
[3.]Mechanical Engineering Department, Universidad Central "Marta Abreu" de Las Villas, (UCLV), CUBA
[4.]Institute of Materials Flow and Logistics. Otto von Guericke University, GERMANY

Abstract: In the research, a wide review of the current literature was carried out, especially of everything related to the storage of products in general, food, international certification of warehouses, warehouses 4.0 and the Cuban resolutions of certification in force. Based on this, a procedure was developed that allows the self-assessment of warehouses with a view to their certification. The work steps it includes consider quality management tools, specific to warehouse management and management in general. Its application increases in complexity as excellence is sought. It was applied to the case study of the finished products warehouse of the Cubay Rum factory in Cuba.
Keywords: Warehouse Management, Warehouse Certification, Warehouses 4.0

INTRODUCTION

Today's business world is becoming increasingly complex and unpredictable for global companies. The changing conditions due to the worldwide spread of the Covid-19 virus pandemic led to increased competition for certain products. The accelerated development of science and technology, together with the globalization of the market, make all organizations, especially Cuban ones, face a race to find solutions that ensure the satisfaction of the population's needs, optimize their processes and improve their competitiveness.

The research takes into account the impact of the fourth industrial revolution or Industry 4.0, and especially observes the Logistics 4.0 that accompanies this evolution. In this context, there are also 4.0 warehouses. Although these technologies are far from the possibilities of most countries, including Cuba, it is interesting to know about them. The interconnection between solutions and software, together with robotics and the management of interaction with people, which connects flexible and intelligent automated solutions with the capacity to expand and adapt to change, are part of the 4.0 version of warehouses.

In the world, warehouses are certified with different standards that respond or adapt to the regulations and standards that the country deems necessary for rigorous compliance with the storage of products according to their characteristics, destinations and consumers. The most common certifications for warehouses are for the construction of the building and the management systems that operate it.

Since the new millennium, different norms and resolutions have been created in Cuba that regulate the procedure for certifying storage systems in the country, as well as who is authorized to categorize them. Since 2007, with Resolution 153 [1] one of the first steps was taken in the creation of a logistic file (EXPELOG) that allows the evaluation of storage systems in companies; it is later complemented with other ministerial resolutions that consolidate the implementation in Cuba. In 2020, the accreditation procedure for storage systems and the requirements to obtain certifications are updated in Resolution 47[2] In addition, Resolution 64[3] creates the National Commission of Experts in Warehouse Logistics, with the objective of controlling and certifying everything related to the category obtained by warehouses in the country and the content of warehouse logistics improvement courses.

Cubay Rum Factury produces high volumes of rums with the premise of satisfying the requirements of its customers, assuring the quality and innocuousness of the productions. Among the expansion plans is the insertion in new markets in Europe; but there are weaknesses, among which is the lack of certification of finished product warehouses by any international European standard for food and beverages. Cuba does not have agencies qualified to certify with these specific international standards; but the new regulation aims to have warehouses evaluated by standards comparable to the most widely used standards or systems in the world, to generate customer confidence and preserve the final quality of the stored product.

Among the methodological tools consulted, several were found to be provided by the authors in the international and national arena. From their study, it was found that they have relevant aspects such as Lean Logistics and the different national procedures for the improvement of warehouse logistics. In the latter, it is always necessary to make adjustments considering the types of products stored, aspects related to the warehouse itself, international experiences and the emergence of new national regulations, in addition to the fact that this procedure can be better structured. The entry into force in May 2020 of the new regulation places the rum company in a position to improve, since it was certified with the first technical level by this regulation. The top management of the company and the Cuba Ron group are not satisfied with the result achieved,

since the first technical level of certification is the lowest of the categories granted.

According to the above, the general objective is defined as: to improve the logistics of the warehouse of finished products of the Cubay Rum Factory.

To achieve the general objective, the following specific objectives are established:

1. Carry out a thorough bibliographic review, which allows to have all the theoretical bases and fundamental applications linked to the subject of the research.
2. Design a procedure for the continuous improvement of the storage logistics of the different presentations of Cubay rum.
3. Apply the proposed procedure to the warehouse of finished products of the Cubay Rum Factory.

In order to meet the objectives, set out in the research, the current storage system in the finished products warehouse of the entity studied is evaluated. In addition to complementing the evaluation with the review of the reports of the audits carried out. Possible corrective actions that the factory can take to improve the system will also be taken into account.

METHODOLOGY

The referential theoretical framework is the search and study of all the literature that is directly related to the research topic[4] Based on the above, the need for the topic under study, the research and analysis of the specialized international and national literature, the review of the state of the art and practice on the subject of warehouse management in logistics chains in general and in particular those of beverages is raised.

— Logistics and Supply Chain Management

Current literature registers more than 35 terminologies to refer to logistics: complex with an integrating, systemic and rationalizing concept, fundamentally oriented to the satisfaction of the final customer of the chain, with the minimum costs and the quality and time required and the quantity and place specified; or simple to give a general idea of the objectives and functions pursued by the same. Researchers and companies use them indistinctly according to the circumstances and objectives they intend to achieve, some of these authors are: [5-9] define that: logistics is that part of supply chain management, which plans, implements and controls the direct and reverse flow and the effective and efficient storage of goods and services, with all related information from the point of origin to the point of consumption, in order to meet customer requirements.

As can be noted, there are many coincidences in the existing definitions that can be summarized in that logistics is a system that comprises the processes of supply, production, distribution, marketing and its reverse chain, which are developed between suppliers and customers, involving the effective and efficient management of material, financial, information and waste flows, having as a premise customer satisfaction.[10].

— Industry 4.0

The world is currently entering the fourth industrial revolution, which is referred to by various authors as the digital revolution or Industry 4.0, where the role of digitalization and IT interconnectivity within industries is prioritized. The term "Industry 4.0" was first used in a high-tech strategy project of the German government. It is based on software nomenclature and is used as a synonym for the fourth industrial revolution. The basic concepts of Industry 4.0 ensure the availability of relevant information in real time by networking all elements involved in value creation, the ability to derive optimal value-adding processes from information and data at any time, and the realization of integrated value-adding process reporting. [11]

Relevant Logistics 4.0 technologies are: identification, mobile communication, localization, electronic data interchange, data analysis methods and data analysis processing. [12] This includes transportation, warehousing and management of raw materials and finished products.

For several years now, there have been several automation systems on the market specially designed to provide automatic picking and storage solutions that increase productivity indicators, reducing the number of movements, transport tasks and space requirements [13]. In this paper we have talked about the fourth industrial revolution or Industry 4.0, the logistics that accompanies this evolution and with it it is also appropriate to identify the Warehouses 4.0. Although these technologies are far from the possibilities of many countries, including Cuba, it is interesting to learn about them in order to incorporate small elements of the same. The interconnection between solutions and software, together with robotics and the management of interaction with people, which connects flexible and intelligent automated solutions with the capacity to expand and adapt to change, are part of the 4.0 version of warehouses.

— Certifications

Considering the author's idea,[14] companies require a rational use of limited resources (inventories, human capital, equipment, space and economic resources). Whether in the management of medicines, industrial supplies, perishable products, electronics, fabrics, food, beverages and others. It is not only important to maintain optimal inventory levels, but also to maintain its properties in good condition and ensure that the worker performs his work in safe environments, so that the offer to the customer is accurate.

Based on their concept of "due diligence" (the ability to be able to demonstrate that all reasonable steps have been taken to avoid an incident), European retailers have established specific standards to ensure logistical, food (and non-food) product quality, safety and legality in the food and beverage supply chain. Food safety standards such as:

- The British Retail Consortium (BRC)
- Germany's International Features Standards (IFS)
- Australia's Small Quantity Generator (SQG)
- The Dutch Hazard Analysis Critical Control Point (HACCP)

These standards are safe and operational management systems, applicable to both food and non-food products. They were created to ensure compliance by the supplier, taking into account storage, transportation and distribution, to ensure the retailer's ability to guarantee the quality and safety of the food products they sell.[15]

All these certifications have one thing in common, the storage standards of the products to be evaluated. This is caused by the different priorities that countries give to the products and their storage conditions.

— Warehouse certification regulations at the national level

The Ministry of Domestic Trade (MINCIN) is the governing body of the country's warehouse logistics activity and therefore in charge of regulating the development of this discipline in the national territory. The following is a brief explanation of the most important resolutions related to warehousing activities and those currently in force. These are: NC 492:2014 [16]: Food Storage. General Sanitary Requirements, currently in force; it establishes the general sanitary requirements to be taken into account for the storage of food products, raw materials and materials used in their preparation.

In 2020; as of May, the Resolution "General Sanitary Requirements for the Storage of Foodstuffs" will be incorporated [2] Resolution 47/2020 defines as objectives: to establish the main regulations in the processes, activities and operations in warehouse logistics of the entities operating in the national economy and to increase the effectiveness and efficiency of the processes, activities and operations related to warehouse logistics based on continuous improvement. It clarifies the agencies with regulatory functions that interact with warehouses. It also explains that: EXPELOG is a mandatory tool to be used in the warehouse and a necessary aspect for its categorization.

Referring to the categorization of warehouses, the resolution states "The categorization process is an institutional act that is executed free of charge, to achieve greater effectiveness in warehouse logistics processes". It is performed according to technological levels:

- First level: When the products are stored in conditions that guarantee their adequate control and conservation.
- Second level: When an adequate organization and operation of the warehouse is achieved.
- Third level: When a correct operation of the warehouse is carried out with a focus on the customer and constitutes a reference warehouse.
- No categorization: When any requirement is not fulfilled in the evaluation process for the categorization of the First Level.

The National Commission of Warehouse Logistics Experts is regulated by Resolution 64/2020[3] This resolution establishes the members and the hierarchy in the commission, as well as their responsibility in the fulfillment of logistics activities.

This study will consider the resolutions issued at the country level in 2020, for the case of storage of inputs and products in general and in particular for the case of beverages.

METHODOLOGY

The procedure developed is the result of the bibliographic analysis carried out, as it contains in a rational manner what has been proposed by the different authors with respect to warehouse logistics, the different resolutions in force in the country related to this activity and the different certifications studied. Figure 1 shows the procedure for improving the storage of Ron Cubay.

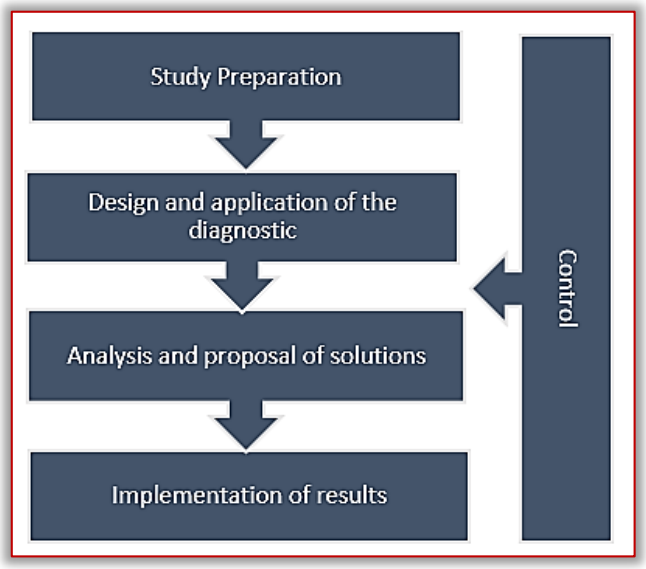

Figure 1: Procedure for improving the storage of Cubay Rum

— Study Preparation

The characterization of the current situation, as the first step or stage of the work, is important in order to have a general knowledge of the organization and in particular of the warehouse under study. For this purpose, it is necessary to describe a whole set of aspects that are detailed below: the corporate purpose, mission, vision, integrated management policy, product lines, strategic analysis of the organization, warehouse layout, analysis of storage technology, technical condition of the equipment, among others.

When assessing the requirements and restrictions demanded by the stored products, compliance with the standards and resolutions established for each type of product stored or to be stored should be taken into account, as well as the specifications described by the manufacturers regarding handling, storage and conservation. It is necessary to evaluate all the activities carried out in the warehouse in order to guarantee the correct handling and conservation, since this result can lead to a significant reduction in logistics costs.

The result of this assessment will make it possible to evaluate the efficiency of the type of installation selected and to propose the optimal-viable technological variant to achieve the best management results. All the requirements and restrictions demanded by the products and the warehouse under study.

— Design and application of the diagnostic tool

This work stage is the core of the warehouse diagnosis and includes the study of the physical installation and its management, preferably qualitatively and quantitatively. The aspects to be analyzed are: space utilization, warehouse organization, reception and dispatch of goods, planning and control, documentation, safety and security, and conservation standards.

For the evaluation of these aspects, several essential tools were used, which are analyzed in the system. These are: checklist (developed to detect problems from a qualitative point of view), storage space utilization indicators, warehouse operation and customer service indicators and cause-effect diagram, which is a qualitative tool, recommended in this case to integrate all the problems detected graphically. Table 1 shows a summary of the checklists and their scores by key areas.

Table 1: Summary of the areas and assessments in the checklists.
Source: Own elaboration

Checklist 1		Checklist 2		Checklist 3	
Aspects to evaluate	Points	Aspects to evaluate	Points	Aspects to evaluate	Points
Constructive state	10	Constructive state	10	Constructive state	10
-	-	Use of space	10	Use of space	10
Warehouse organization	30	Warehouse organization	20	Warehouse organization	15
Planification and control	15	Planification and control	10	Reception and dispatch of the merchandise	10
Documentation in the warehouse	10	Documentation in the warehouse	10	Planification and control	10
Conservation and pest control standards	10	Conservation and pest control standards	10	Documentation in the warehouse	15
Protection, Safety and health of workers	15	Protection, Safety and health of workers	10	Conservation and pest control standards	10
-	-	Equipment	&	Protection, Safety and health of workers	10
-	-	Cleaning and disinfection	10	Equipment	&
Product contamination	10	Product contamination	10	Product contamination; Cleaning and disinfection	10
Total	100	Total	100	Total	100

It is important to point out that in order to reach a level of categorization, all aspects of the previous level and the level for which it is chosen must be fulfilled. This is represented in the checklists, as this avoids losing achievements that have already been reached. The three checklists will have a value of 100 points each, although the values of the evaluated areas and aspects vary according to the technological level.

Checklist 2 is applied in the research, by way of example some of its unique characteristics are highlighted in the points that most affect the evaluation of the warehouse. These are:

≡ Use of space:
- ✓ Digital organization of the warehouse.
- ✓ I work with the scanner and codes on the secondary packaging.
- ✓ Use of machinery to avoid double manipulation.

≡ Organization of the warehouse:
- ✓ The effectiveness of control methods.
- ✓ Construction facilities for reception and dispatch.
- ✓ Procedures or technologies to reduce handling.
- ✓ Training of workers in logistics and in the use of equipment in their work area.

≡ Warehouse documentation:
- ✓ Traceability.
- ✓ Skills with computers and data processing.

≡ Equipment
- ✓ The equipment on the technological floor is connected by network or WIFI in the warehouse.
- ✓ There is human-machine interaction in the automatic or semi-automatic activities of the warehouse.

It should also be noted that as the level of certification increases, the number of areas to be evaluated increases and the scores between the areas in the different levels of certification also change.

— Analysis and proposals for solutions

For the development of corrective actions, the starting point is an analysis of the storage technology. This factor is a determining factor in defining the form of storage to be selected.

Once the problems have been identified, a set of actions aimed at eliminating or minimizing the problems detected must be proposed. For the execution of the corrective actions, the conditions of the warehouse and the product of the factory must be taken into account, where the possible solutions tend to increase the economic results and the service to the client.

For the generation of corrective actions, the use of the expert method known as Brainstorming is recommended, in which workers, specialists and managers should participate, being essential the following: quality specialist, warehouse clerks, economic specialist, commercial manager (recommended as facilitator), members of the inventory commission, commercial analyst, distribution specialist.

— Implementation of the results

This work step constitutes an ordering of the results of the previous step. It involves drawing up an implementation plan for the proposed corrective actions, using the format in Table 2.

Table 2. Implementation Plan

Deficiency	Measure	Responsible	Participants	Compliance Date

At this stage, the implementation of the technological reorganization design of the warehouse is proposed for a trial period of 6 months. The commercial manager will systematically meet with those responsible for applying each measure and verify compliance with the implementation plan. If any corrective action requires staff training, this manager will coordinate with the Human Resources area.

— Control

The last step of the procedure is a control loop to rectify any deviations detected during the 3-month period of operation of the warehouse. The checklist and indicators proposed in the diagnostic stage are used again to verify whether the problems have been mitigated or eliminated and the indicators meet the requirements of Resolution 47/2020.[2] If this does not occur, return to the work step of the corresponding procedure and repeat the rest of the procedure. On the other hand, if the warehouse is ready for categorization, the EXPELOG is prepared in the format suggested in the aforementioned resolution.

RESULTS AND DISCUSSION

The warehouse is in the first level of categorization, the checklist is applied to obtain the second level of categorization; a value of 76 points is obtained. Figure 2 shows a summary of the main problems that affect the evaluation of the warehouse in a Cause-Effect or Ishikawa diagram.

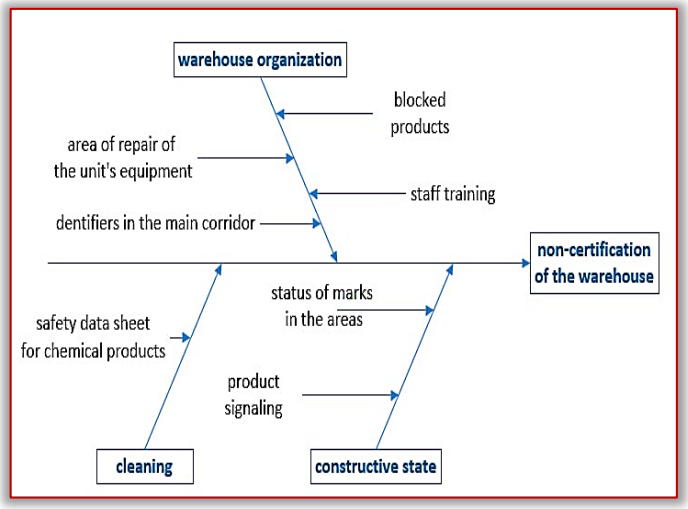

Figure 2: Cause-Effect diagram or Ishikawa

Once the problems have been identified, a set of actions aimed at eliminating or minimizing the problems detected must be proposed. For the execution of the corrective actions, the conditions of the warehouse should be taken into account, where the possible solutions tend to increase the economic results and customer service. A series of actions are recommended according to the results implementation plan, which are shown in Figure 3.

Deficiencia	Acciones correctoras propuestas	Responsable	Ejecutor	Fecha de cumplimiento
Mal estado de las líneas del piso en las áreas de estibas directas.	Pintar las áreas de estibas directas, con líneas preferentemente amarillas de diez (10) centímetros de ancho.	Jefe de almacén	Departamento Mantenimiento	Julio 2021
Se observan productos bloqueados en el almacén.	Organizar por pedidos de los clientes, para evitar la doble manipulación y los productos bloqueados.	Jefe de almacén	Trabajadores del almacén	Julio 2021
No existe el área de reparación, los medios unitarizadores se mueven con la mercancía.	Exigir la recepción en buen estado de los medios unitarizadores por parte de los clientes. Además, la reposición en caso de roturas.	Director comercial	Jefe de almacén	Julio 2021
Los lotes no tienen un identificador en los pasillos principales.	Facilitar marcadores o tarjetas para identificar los lotes en los pasillos principales.	Director comercial	Jefe de almacén	Julio 2021
El personal no está capacitado.	Crear plan de capacitación para el personal del almacén.	Director de RRHH	Trabajadores del almacén	Septiembre 2021
No existen las fichas de datos de seguridad para todos los productos químicos de limpieza.	Agregar al plan de limpieza la ficha de los datos de seguridad de los productos químicos utilizados.	Director comercial	Jefe de almacén	Julio 2021
No se señalizan los diferentes grupos de productos.	Marcar en los pasillos principales los diferentes tipos de productos.	Director comercial	Jefe de almacén	Julio 2021

Figure 3: Implementation Plan

The way to validate the result is to apply again the checklist for the second level of certification, considering that most of the problems are solved. Table 3.1 summarizes the results of the application of the checklist in the warehouse. This checklist revealed the following problems in the different aspects evaluated in the warehouse.

Table 3. Summary of the results of the re-qualification of checklist two for the second technological level

Aspects to be evaluated	Qualification	Quantitative evaluation	Qualitative assessment
Constructive state	10	10	Not bad
Use of space	10	10	Not bad
Warehouse organization	20	16.5	Not bad
Planning and control	10	9	Not bad
Warehouse documents	10	10	Not bad
Conservation and pest control standards	10	10	Not bad
Protection, Safety and health of workers	10	10	Not bad
Computers	&		Not good
Cleaning and disinfection	10	10	Not bad
Product contamination	10	10	Not bad
Total	100	95.5	Not bad

Progress is being made in the ratings obtained in several aspects, but the aspect related to the waterproofing of the roof is an invalidating aspect. Although Cubay Rum Factury has designed a training plan for warehouse personnel, it has not been possible to implement it due to Covid-19 restrictions.

CONCLUSIONS

- The literature consulted provided the theoretical basis, among which the following stand out: supply chain management, warehouse logistics, international resolutions and those existing in the country, among other aspects. This is subsequently applied according to the specific characteristics of the entity under study.
- The procedure used constitutes the main scientific contribution. It contains methods and instructions for the categorization of the warehouse, as well as qualitative and quantitative tools, ranging from the determination of indicators, to the use of checklists and cause-effect diagrams, by means of which the diagnosis and improvement of the warehouse under study is carried out.
- The main contribution is the adaptation of the checklists to each desired certification level, according to the current Cuban resolution for the certification of warehouses and with it, of the corrective actions and the implementation plan. These adaptations are based on the requirements made to the rum storage process, taking into account the logistic norms of the warehouses, the resolutions for working with food products and the new food safety law.
- It is considered that the proposed general objective was achieved by developing a procedure for the analysis and improvement of warehouse management for the finished products of Cubay Rum Factury, which will enable it to advance in its level of certification in a relatively short period of time.
- Apply the proposed procedure to other supply chains, determining the changes that the proposed tools may undergo according to the selected chain; this will allow designing and implementing new research to contribute to enhance the certification of warehouses in different food supply chains.

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[1.]Mihai OLAN, [2.]Petru Marian CÂRLESCU, [1.]Valentin VLĂDUŢ, [1.]Anişoara PĂUN, [3.]Elena TROTUŞ, [3.]Lorena–Diana POPA, [1.]George BUNDUCHI, [1.]Alexandru ZAICA, [4.]Alexandru–Polifron CHIRIŢĂ

CFD SIMULATION OF AN INNOVATIVE SYSTEM FOR HEMP SEEDS DRYING

[1.]National Institute of Research – Development for Machines and Installations Designed to Agriculture and Food Industry – INMA, Bucuresti, ROMANIA
[2.]USAMV Iaşi, ROMANIA
[3.]SCDA Secuieni, ROMANIA
[4.]INOE 2000 – Subsidiary Hydraulics & Pneumatics Research Institute, ROMANIA

Abstract: Obtaining a temperature and humidity gradient as uniform as possible during drying is important in obtaining quality dried hemp seeds. To this end, active control equipment for drying hemp seeds has been designed. The article aims to simulate the flow of hot air in the equipment with active control for drying hemp seeds in order to obtain the distribution of the field of velocities, temperatures and relative humidity in the hemp layer that is subjected to drying. The present study proposes an innovative concept in the construction of a polygonal dryer for hemp seeds harvested from experimental plots. By simulating the CFD (Computational Fluid Dynamics) of the innovative dryer for hemp seeds, in this paper we obtain 3D representations of the flow field of the drying agent within the technological drying process. In case of drying the hemp seeds that will be used for sowing, by simulating the dryer, optimal values of the working parameters (velocity and temperature) are obtained, in order to preserve the superior germination quality of the hemp seeds.
Keywords: numerical simulation, drying process, hemp

INTRODUCTION

The equipment is used for drying hemp seeds harvested from experimental lots. The technological system includes a support with 3 elements of perforated sheet that distributes heat, a metal housing that includes the constructive elements of the system, two sliding systems with plates positioned with linear guides and driven by two mechanisms screw–nut with hand wheel that allows unloading seeds in the tubs of two conveyor belts with squeegees and which have a discharge hopper provided with an adjusting device.

Many mathematical models have been developed to simulate the heat and the moisture transfer in aerated bulk stored grains (Amini, G., et al, 2021). The models were obtained at relatively low temperatures and low humidity to grain (Cârlescu P., Arsenoaia V et al, 2018). The models simulated forced convective heat and moisture transfer in vertical direction (Cârlescu P., Tenu I.,2018; Cârlescu P., Arsenoaia V, et al,2017), but the model was not validated (Chang,C. et al., 1994) and (Sinicio,R. et al., 1997) developed a rigorous model to predict the temperature and moisture content of wheat during storage with aeration(Guaita, M., Panero, L, et al,2021) and found that prediction result is in reasonable agreement with observed data (Thorpe, 2008) calculated on CFD models to a software that simulates heat and moisture transfer in the bad grain. Based model and simulation of (Thorpe, G.R., 2008; Muscalu, A. et al., 2016) developed and validated by experimental measurements of temperature transducers introduction the theoretical model at different points in a grain silo (Inada, K., Ohanna, P, et al, 2020).

Obtaining a temperature and humidity gradient as uniform as possible during drying is important in obtaining quality dried hemp seeds (Kenenia, Y.G., Hvoslef–Eideb, A.K.et al, 2019). To this end, active control equipment for drying hemp seeds has been designed. The article aims to simulate the flow of hot air in the equipment with active control for drying hemp seeds in order to obtain the distribution of the field of velocities, temperatures and relative humidity in the hemp layer that is subjected to drying (Muscalu A., Cârlescu P., 2018)

Knowing the temperature distribution in the hemp layer indicates the uniformity of heating and drying, respectively. By knowing the humidity profile of the intergranular air in the hemp layer, it is possible to optimize the flow and temperature of the hot air at the entrance to the equipment with active control for the drying hemp (*Wen–Bo, M., Yan–Yan, N, et al, 2021*).

MATERIALS AND METHODS

The active control equipment for drying hemp seeds is designed to achieve a gentle drying of the seeds to keep their germination power active. The CFD (Computational Fluid Dynamics) simulation was performed to obtain high–performance equipment in the drying operation.

The geometry of the equipment with active control was conditioned by the shape of the dryer chamber, being made with four regions of layer drying of hemp seeds, provided with three perforated distributors introduced in the layer with the role of drying uniformity and which are coupled to a central distributor. warm air. The lateral introduction of hot air into the drying equipment was imposed by technological conditions. The active control equipment for drying hemp seeds is shown in Figure 1, and the simplified geometry of the equipment necessary for CFD simulation and its composition is presented in (Figure 2).

The discretization of the geometry of the equipment with active control for drying hemp seeds is unstructured being performed with the Ansys–Gambit program (Figure 3). In the region of those distributors and the layer of hemp seeds subjected to drying, the discretization was performed with a

larger number of knots. Discretization was performed with a sufficiently large number of volumes so that the accuracy of the results was not affected and the computation time was reasonable. The average number of nodes resulting from the discretization was 1,594,075, and the quality of the discretization was 0.7.

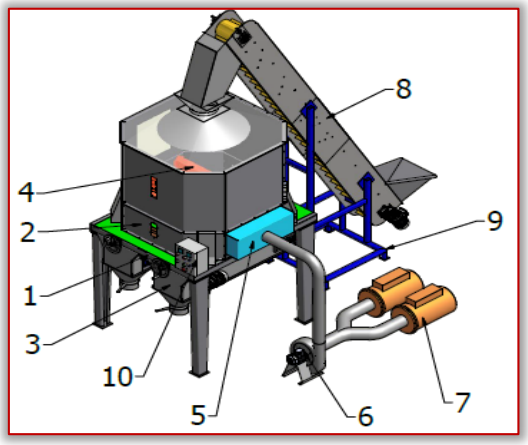

Figure 1 – Equipment with active control for drying hemp seeds:
1–support; 2–housing; 3–lane unloading; – drying cap; 5– hot air distributor; 6 – hot air fan; 7–hot air generator; 8–band seed transport; 9–support conveyor belt; 10–electrical panel for command and control

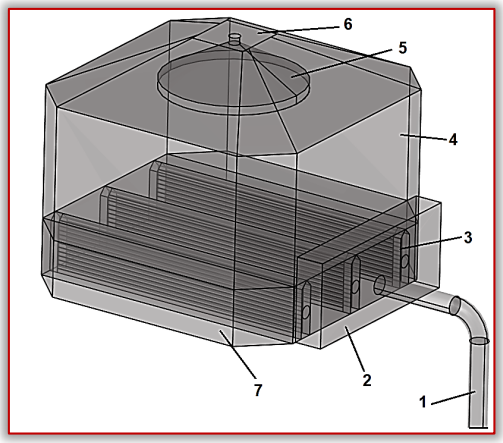

Figure 2 – Geometry of the equipment in CFD simulation:
1–hot air inlet duct; 2– central hot air distributor in the equipment; 3– perforated hot air distributor; 4– wall dryer; 5– cone distribution of hemp seeds; 6– used drying agent outlet; 7– layer of hemp seeds subjected to drying

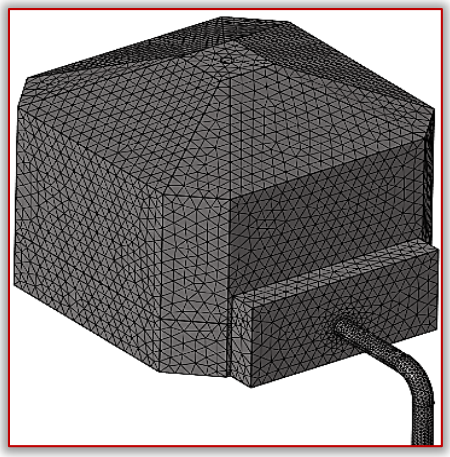

Figure 3 – Grid for geometry of the drying equipment

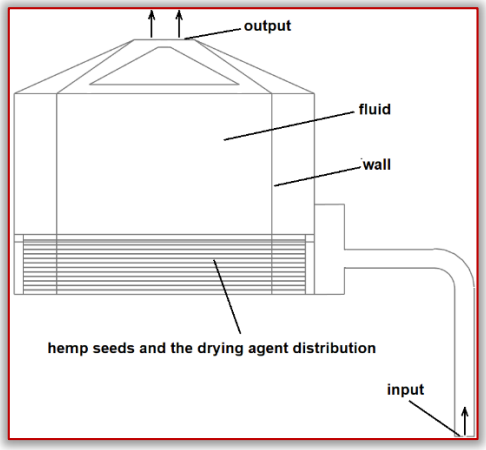

Figure 4 – Boundary condition for the CFD simulation

The discretization of the geometry of the equipment with active control for drying hemp seeds is unstructured being performed with the Ansys–Gambit program (Figure 3). In the region of those distributors and the layer of hemp seeds subjected to drying, the discretization was performed with a larger number of knots. Discretization was performed with a sufficiently large number of volumes so that the accuracy of the results was not affected and the computation time was reasonable. The average number of nodes resulting from the discretization was 1,594,075, and the quality of the discretization was 0. 7.

Table 1. Boundary conditions for drying equipment

Boundary sections	Boundary conditions
Inlet	velocity v=ct.; temperature T_a=ct; moisture X_a= f(τ)
Outlet	p=0
Wall	$\partial v/\partial n = 0$ (n – normal to the surface)
Volums	fluid (air)/solid bed (hemp)

Through the drying equipment, hot air flows from the central distributor to the three perforated distributors positioned in the hemp seed layer with the role of uniformizing the drying agent in the seed layer. In the CFD simulation processing stage, the conditions necessary for the calculation to determine the speed, temperature and relative humidity field inside the drying equipment were introduced. The conditions introduced are presented in Table 2.

Table 2. Processing conditions

v (m/s)	T_a(K)		X_a (Kg water/Kg dry air)	ρ_a (kg/m^3)	η (kg/ms)	C_{pa} (J/kgK)
	input	wall				
20	303.15	293.15	X_a= (τ)	1.225	$1.9\cdot10^{-5}$	1006

where: ρ_a density of air, η dynamic viscosity of air; C_{pa} specific heat of air, τ time for drying.

The absolute humidity of the air entering the drying equipment varies over time according to the function presented in Table 3.

Table 3. Function of entry into the drying equipment

X_a (Kg water/Kg dry air)	$X_a = -2\cdot10^{-12}\cdot\tau^2 + 6\cdot10^{-7}\cdot\tau + 0{,}0094$

The flow regime at the inlet of hot air into the drying equipment is laminar, being determined according to the

Reynolds criterion. The thickness of the layer of hemp seeds in the dryer is 400 mm, and the initial humidity of the seeds is 30%. The thermophysical characteristics of wet hemp seeds are introduced in the simulation as average values (ρp = 725 kg/m^3, Cpp = 1985 J / kgK, product conductivity K = 0.117 W / mK). The porosity index of the hemp seed layer is introduced in the simulation with the value of 0.3, considering the seed layer as homogeneous and isotropic. CFD simulations were performed in a non–stationary regime with a drying time duration of 7 hours. Drying simulation was performed with the DELL workstation (2XCPU–Intel Xeon 22 core 3.33GHz; 128 GB RAM DDR4ECC).

RESULTS AND DISCUSSION

The results of the simulation are presented in the form of the fields of speed, temperature, humidity and respectively the trajectory of the power lines in the simulation field of the drying equipment. The CFD simulation was performed both for the drying equipment without hemp seeds and with hemp seeds distributed in a uniform layer of constant thickness. The three–dimensional simulation of the hot air flow in the drying equipment without hemp seeds shows the field of the power lines with the variable temperature (Figure 5).

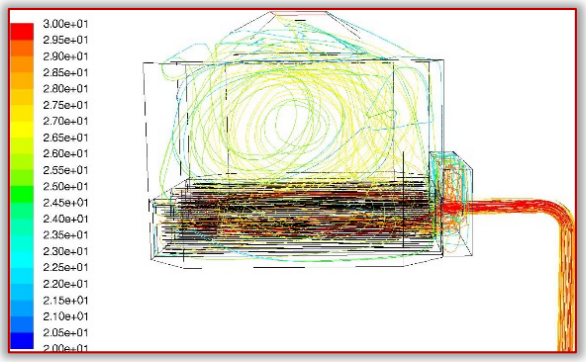

Figure 5 – The temperature pathlines of the warm air inside the drying equipment without hemp seeds

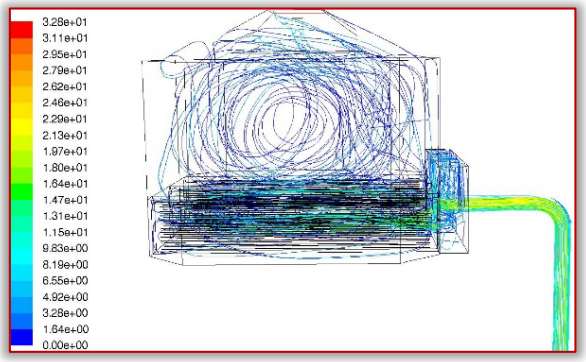

Figure 6 – The velocity pathlines of the warm air inside the drying equipment without hemp seeds

This distribution of the power lines shows the flow of hot air at the level of the seed layer, but without them existing in the layer, showing the speed distribution (Figure 6). The profile of the temperature and speed field in a YOZ plane in the middle of the seed drying equipment, without hemp seeds is shown in Figure 7 and Figure 8.

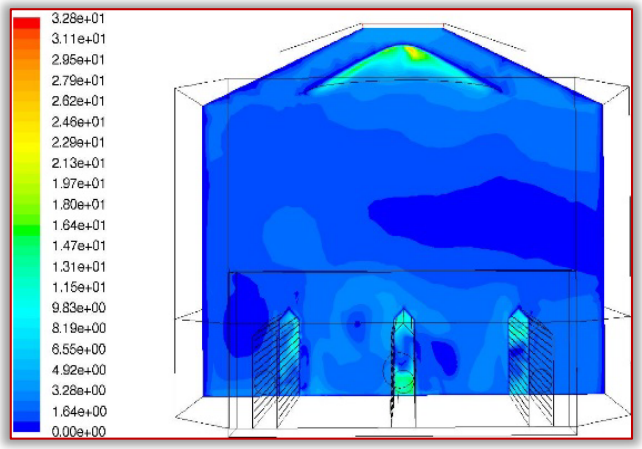

Figure 7 – Air velocity field in the transverse plane of the drying equipment (m / s)

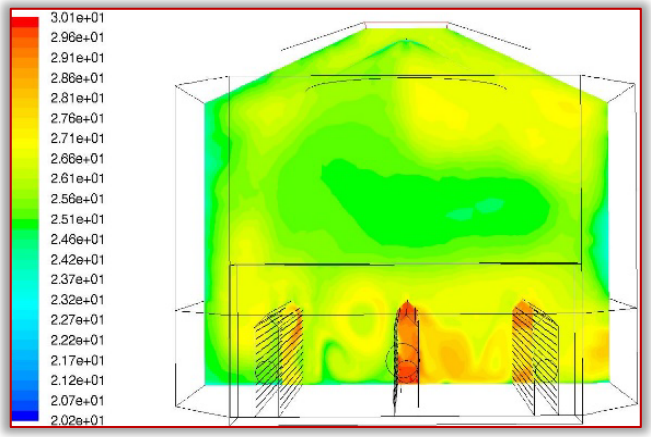

Figure 8 – Air temperature field in the transverse plane of the drying equipment (°C)

From the figures of the distribution of the speed and temperature of the hot air in the equipment without seed layer, the non–uniformity of the distribution at the level of the seed layer region can be observed.

In order to verify the distributions of the temperature and relative humidity fields of the thermal agent inside the drying equipment, when a layer of wet hemp seeds was introduced inside, a new CFD simulation was performed.

By introducing a layer of hemp seed evenly distributed in height in the drying equipment, it is expected that the degree of uniformity of the drying agent temperature in the layer will increase due to the aerodynamic resistances of the seed layer with uniform porosity of 0.3, according to Figure 9, Figure 10, Figure 11, and Figure 12.

An improvement of the uniformity of the speed field of the drying agent in the seed layer also attracts an improvement of the uniformity of the temperature field with values between 24.8^{0}C and 27.1^{0}C. The decrease in the air temperature in the layer compared to the air temperature used as a drying agent (30^{0}C) occurs as a result of the drying process by removing moisture from the hemp seeds. Also, at the walls of the dryer was considered in the simulation a temperature of 20^{0}C. In practice, towards the end of drying the hemp seeds the temperature reaches approximately equal to the temperature of the drying agent.

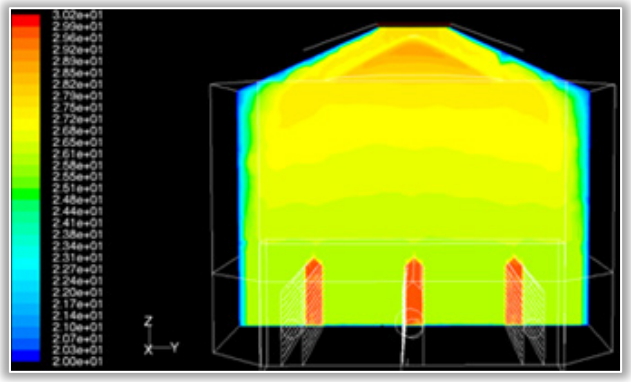

Figure 9 – Transverse plane (YOZ) air temperature field of hemp seed drying equipment (°C)

The temperature field also varies on the vertical of the seed layer (Figure 10, 11, 12) so at the base of the layer the temperature has an average value of 25.8°C, in the middle of the layer the temperature increases with the value of 27.1°C, reaching as in the upper plane of the layer the temperature should drop to 24.8°C. This temperature stratification is explained by the migration of moisture to the top of the seed layer which is finally removed by air to the top of the drying equipment.

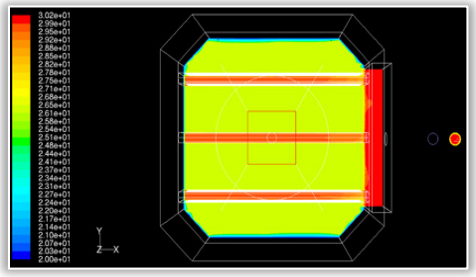

Figure 10 – Temperature field in the plane at the base of the hemp seed layer (°C)

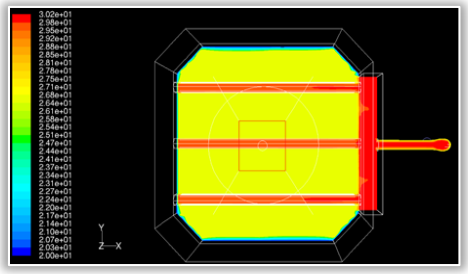

Figure 11 – Temperature field in the plane in the middle of the hemp seed layer (°C)

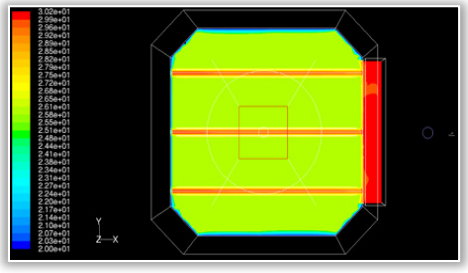

Figure 12 – Temperature field in the upper plane of the hemp seed layer (°C)

In order to verify the air humidity gradient in the hemp seed state of the drying equipment, a new simulation was performed in which the technological parameters previously used to simulate the flow of hot air used as a drying agent were introduced. The results of the CFD simulation regarding the humidity field are presented in the XOY and YOZ planes, respectively, inside the drying equipment with hemp seeds according to Figure13 and Figure 14.

Following the simulation analysis in the drying process, the relative humidity distribution in the XOY plane in the middle of the hemp layer has higher values near the perforated distributors due to the more pronounced moisture loss of the seeds, the intergranular air reaching a relative humidity of up to 81.9%, in the center of the layer the air reaches a relative humidity of 67.1%, and in the wall area the humidity reaches 58.2% (Figure 13). Analyzing the relative humidity profile of the YOZ cross–sectional plane, it is observed that the distribution is kept high near the perforated distributors through which the hot air passes with a relative humidity of 37%, therefore the highest moisture loss of hemp seeds is near distributors and a lower loss in the center of the layer and near the walls of the dryer (Figure 14). During the drying of hemp seeds, this uneven distribution of the relative humidity of the air is directly reflected in the uneven moisture of the seeds in the layer, showing that in the middle of the layer and near the walls of the dryer the seeds lose moisture more difficult. As a result of the uniformization of the temperature in the layer (Figure 11) towards the end of drying, the humidity of the seeds in the layer becomes uniform at an average value of preservability.

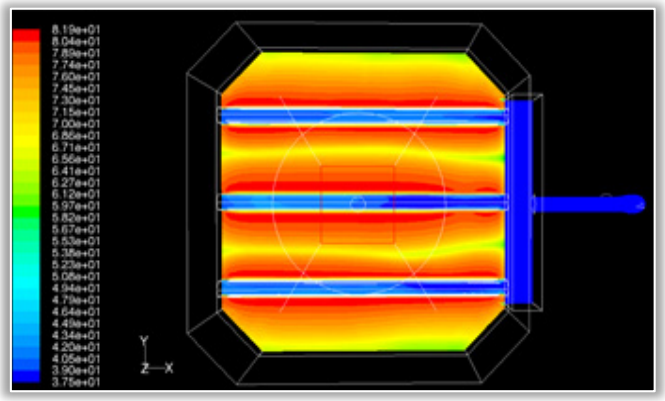

Figure 13 – The relative humidity of the warm air inside the drying equipment with hemp seeds in XOY plane (%)

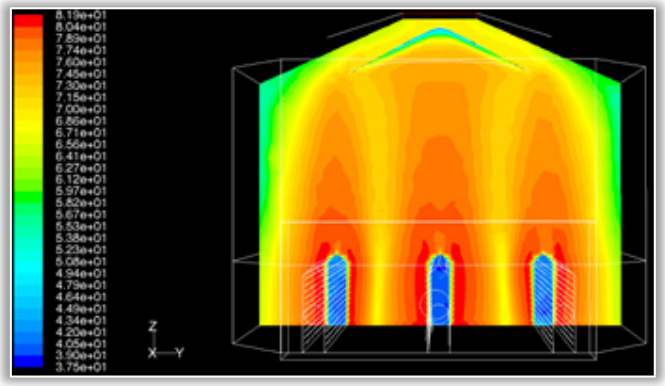

Figure 14 – The relative humidity of the warm air inside the drying equipment with hemp seeds in YOZ plane (%)

The CFD simulation of the active control equipment for drying hemp seeds requires a calibration by taking the experimental data from the drying equipment for the parameters of speed, temperature and relative humidity of

the hot air at the equipment inlet, as well as by repeated determinations of temperature and humidity. on three different heights and between distributors in at least three points in the state region, both without and with a layer of seeds.

Also, in order to increase the accuracy of the simulated model, it is necessary to take samples at the end of drying the hemp seeds and to determine the humidity from different points of the seed layer by three repetitions.

The technological system includes a support with 4 elements of perforated sheet that distributes heat, a metal housing that includes the constructive elements of the system, two sliding systems with plates positioned with linear guides and driven by two mechanisms screw–nut with hand wheel that allows the unloading of seeds in the tubs of two conveyor belts with squeegees and which have a discharge mouth provided with a syringe. during the drying of the seeds then it opens to remove moisture and supply the seeds for a new drying cycle. The heat source is made with the help of two electric air heaters that ensure the optimum temperature of 28–30^{0}C and a flow of 2500 m^3 / time required for the drying process.

The seed supply is made with a scraper conveyor belt that is positioned and placed on a metal support. The electrical panel includes the controls for the feed conveyor belt, the unloading conveyor belts, the control of the high pressure centrifugal fan that ensures the necessary flow and control of the two electric air heaters. The fan speed is regulated with a frequency converter. For the temperature control inside the dryer is mounted a thermometer with electronic display. The humidity check is done with a special equipment for humidity control for cereal seeds. The entire technological process can be monitored and adjusted automatically with a process computer.

Technical data: inlet humidity: 25–30%; output humidity: 10–12%; warm air temperature: 28–30^{0}C; hot air flow: 2400 m^3 / hour–productivity: 500 Kg / batch; the system works in semi–automatic mode with a technological process computer for adjusting temperatures and air flow.

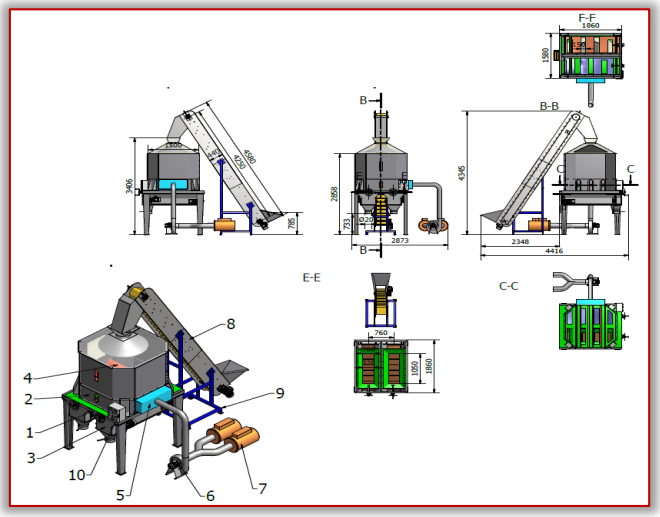

Figure 15 – Constructive diagram of the equipment

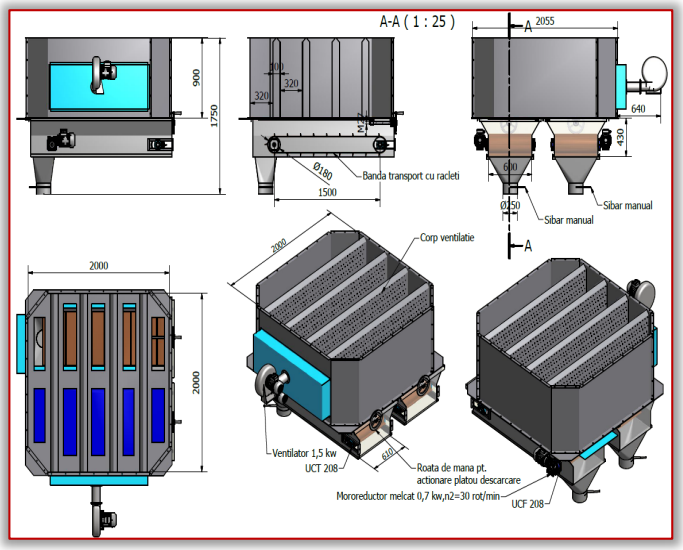

Figure16 – Dryer body

1 – Support; 2 – Housing; 3 – Unloading belts; 4 – Dryer cover; 5 – Hot air distributor; 6 – Hot air fan; 7 – Hot air generator; 8 – Seed transport belt; 9 – Conveyor belt support; 10 – Electrical panel for command and control

Technical advantages over known solutions:

- Compact construction that ensures uniform heat distribution in the entire number of seeds;
- Low electricity consumption due to the adjusting device closing system at the top of the dryer;
- Active control and automatic reclassification of the parameters during the technological drying process

CONCLUSION

The CFD simulation of the hot air flow through the active control equipment for drying hemp seeds can lead to the optimization of its constructive form.

By the constructive optimization, both the constructive shape of the box and the thickness of the layer of hemp seeds subjected to drying are obtained by following the temperature gradient correlated with the movement of the air inside the dryer.

The temperature difference obtained by CFD simulation in the hemp seed layer is 2.3 °C, and the differences in relative humidity of the intergranular air in the seed layer is 23.7%.

By calibrating the CFD simulation with experimental predetermination, a drying equipment with optimal technological performance for drying hemp seeds is obtained.

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[1.]Mariana Mădălina STANCIU, [1.]Florin NENCIU, [1.]Ancuţa Alexandra PETRE,
[1.]Nicoleta Alexandra VANGHELE, [1.]Andreea MATACHE

AERATION SYSTEMS USED FOR THE OPERATION IN OPTIMAL PARAMETERS OF FISHING PONDS

[1.]National Institute of Research – Development for Machines and Installations Designed to Agriculture and Food Industry – INMA, Bucuresti, ROMANIA

Abstract: Intensive fish farming practices involve efficient management of aquatic ponds, in order to obtain high and sustainable production yields. In order to maintain the maximum production levels and to ensure quality products, ponds operating staff have to address to a wide range of major importance issues such as water quality, disease and pathogens control, aquatic vegetation, sedimentation, and fish control strategies. Managing dissolved oxygen levels in ponds is a major concern in aquaculture because involves understanding the aeration principles and natural pond dynamics, attributable to biological and chemical processes. Aeration equipment functioning is dependent on a number of external factors such as fish and plants density season, the type of pond that is being used and weather patterns. This paper presents practical information related to the use of aeration equipment in ponds, the importance of artificial aeration in aquaculture, as well as the impact of aquaculture on the environment.
Keywords: aquaculture, aeration, dissolved oxygen, pump sprayer aerator

INTRODUCTION

Aquaculture is an economic activity that uses a set of well-established techniques used to transform aquatic natural resources, such as fish, shellfish, mollusks, aquatic plants into commodities for society (Troell et al., 2013). In order to meet the growing demand for food, the growth and sustainable development of the aquaculture sector, which plays a key role worldwide, has an essential role (Kobayashi M et al., 2015). The ecological conditions for fish development depends on certain water quality parameters, such as: dissolved oxygen, total ammonia-nitrogen ratio, total alkalinity, free CO_2, total hardness and planktonic life in the pond (Hepher and Pruginin, 1981; Ali et al., 2000).

A wide variety of aquatic culture organisms are used worldwide in aquaculture, they can grow in different types of environment such as: freshwater, saltwater and marine. Freshwater aquaculture is carried out in fish farms, in fish cages, in ponds or rice paddies, while saltwater aquaculture is usually carried out in fish ponds in coastal areas (Perry L. Oakes et al., 2011).

Artificial aeration is a method that has a positive impact on pond productivity, thus increasing the growth and production of fish at high storage densities, and the use of aeration equipment in aquaculture ponds depends on a very well-developed management (Perry L. Oakes et al., 2011).

In an intensive aquaculture system, increased fertilization, overfeeding and high storage density lead to insufficient natural aeration, and this may become a limiting factor for production. Therefore, a very good method is artificial aeration, being a beneficial alternative for the survival of flora and fauna, since it leads to a rapid and healthy growth of crop species (Tanveer et. al., 2018).

In fish ponds with large stocks and artificially fed, numerous problems frequently occur, such as organic pollution, oxygen deficiency, increased levels of free carbon dioxide and the total increase in the ammonia-nitrogen ratio. Aeration is an appropriate way to address them (Agarwal, 1999; Boyd, 1995).

Boyd (1990) reported that the aeration system is one of the best methods of oxidizing ammonia to nitrates or adjusting the pH and volatilization of ammonia in water.

Artificial aeration is a suitable way to eliminate the negative effects that can frequently occur in ponds, such as high CO_2 levels, organic pollution, increased ammonia-nitrogen ratios and oxygen deficiency. It is one of the best methods for stabilizing the pH of water, oxidizing ammonia and volatilizing ammonia (Agarwal, 1999; Boyd, 1995)

— The importance of aeration in fish ponds

Air is a vital element for the maintenance of life, and the need for dissolved oxygen in aquaculture ponds is obtained by photosynthesis of aquatic plants, by diffusion from the atmosphere on the water surface, and by artificial aeration systems, which keep dissolved oxygen in normal parameters when it decreases. Dissolved oxygen from aquaculture ponds is one of the most critical limiting parameters and is a very important factor in terms of water quality and underwater life, as aquatic organisms require a constant supply of oxygen to perform respiration and other biological activities, and food waste from water will be oxidized efficiently (Tanveer M., 2017).

When the dissolved oxygen supply increases, the anaerobic decomposition in the pond is performed in optimal conditions, as well as the nitrification process and other processes.

The aeration of the pond makes a significant contribution to the cultured fish, thus satisfying their normal metabolic demand, and ensuring optimal oxygen levels (worldfishcenter.org).

Depending on the decrease in dissolved oxygen concentration, risks may occur: fish may become more

prone to infectious diseases, consume less feed and process it less efficiently, the growth rate of fish will decrease, and there is a risk of suffocation of fish, causing their death. In addition to all these negative effects caused by the decrease in dissolved oxygen in aquaculture basins, that decrease will affect the entire aquatic ecosystem.

— Oxygen consumption by fish

The different fish species have become adapted to different living conditions during their evolution. There are fish species with high oxygen requirements, for which only small variations in the amount of oxygen can cause major developmental damage, while some other species such as Cyprinids are less demanding of oxygen. In addition, in some tropical areas there are species of fish that have the ability to breathe through the skin, and other species have internal organs with specific functions similar to the lungs.

Standard oxygen consumption is the quantity of oxygen needed by fish for subsistence, consumed without swimming and feeding. Have been noted that standard oxygen consumption is not dependent on oxygen saturation of the water but it is significantly influenced by water temperature.

— Principles of aeration

Normally, aeration of an aquaculture pond is accomplished by transferring gaseous oxygen from the atmosphere to the pond water, where dissolved oxygen concentrations have dropped below normal. Depending on certain factors, such as the amount of turbulence in the water, the ratio of the pond surface to its volume and how far the measured DO concentration deviates from the saturation concentration (ie, when the relative amount of oxygen in the atmosphere is equal to DO concentration in water), this deviation is called either saturation deficit or surplus, depending on the measured concentration of dissolved oxygen.

Especially salinity and temperature are the water quality parameters that predominantly influence the dissolved oxygen saturation. Mechanized aerators are machines that improve the mixing of water in the pond, therefore it reduces thermal stratification and can increase the content of dissolved oxygen needed by aquatic organisms, but at the same time helps to distribute feed and eliminate waste from the pond (Hargreaves et al., 2004).

TYPES OF AERATORS

The best choice of aeration system is normally made, depending on the following factors: seasonal changes, pond shape, pond depth, its size, aerator efficiency, fish harvesting methodologies, power supply availability and type of aeration. Aerator performance is measured as standard oxygen transfer rate (SOTR) or standard aeration efficiency (SAE).

SOTR is the amount of oxygen added to water within 1 hour under standard conditions, and is expressed in kg / hour of O_2. The SAE is the standard oxygen transfer rate divided by the power (CP) of the unit, expressed in kilograms of O_2 / hp-hour transferred to water (Boyd C.E, 1998).

The correct location and positioning of the aerators in the ponds aim at obtaining a good water circulation and the distribution of saturated oxygen water on the entire surface of the pond (Tanveer M. and Nadu T, 2017). Aquaculture aerators are similar to those used in wastewater aeration. However, modified aerators have been developed for aquaculture that are less expensive than those for wastewater.

This equipment helps to increase the turbulence in the body of water and the surface of the water in contact with the air, thus influencing the rate of oxygen transfer from air to water. The most common types of aerators used in aquaculture require electricity or fuel-powered motors (tractors or pumps), these are: pump sprayers, vane wheels, vertical pumps, propeller-vacuum pumps, spiral wheel aerator and air systems diffuse (Wurts W.A., 2019).

PUMP SPRAYER AERATORS

Pump-sprayer aerators are simple, low-maintenance equipment, being a suitable choice for emergency aeration operations, with good efficiency on a small area of the pond and can be powered by an electric motor or power take-off (Tucker C., 2005).

Figure 1. Pump sprayer aerator in operation (http://extension.msstate.edu/news/feature-story/2017/smaller-catfish-ponds-intensify-production)

Spray aerators have a high pressure pump with which artificial aeration is performed. This pump discharges water at high speed through one or more of its holes, the water is pumped upwards, and then falls to the surface of the water in an umbrella pattern (Boyd C.E, 1998). These are mobile equipment, easy to transport from one pond to another and can operate even at shallow depths, provided that the pump inlet is sufficiently submerged in water (Tucker C., 2005).

The disadvantage of pump sprayers is that they can improve the concentration of dissolved oxygen only in their vicinity and are more effective in aerating the bottom of the pond, but they can also be combined with other types of aerators for higher efficiency (Rogers G.L., 1989).

In the case of this type of aerator, the dissolved oxygen concentration is improved only near the equipment, and the

water regions in the distance remain unventilated (Rogers G.L., 2009).

According to the literature review, research on performance evaluation and economic analysis of a pump spray aerator is limited to none.

VERTICAL PUMPS

Vertical pump aerators operate on the same principle as pump sprayer aerators and consist of a relatively small electric motor with one or two rotors, which rotate at 1730 or 3450 rpm, which are attached to the motor and suspended on the surface of the water with the help of a float.

Due to the fact that this type of aerator has a relatively small engine, its use is limited to ponds smaller than 1 acre. These aerators are manufactured in sizes <1 to 50> Kw, but aquaculture units are rarely larger than 2 Kw (Boyd C.E., 1998).

Figure 2 – A vertical pump aerator in action (Boyd C.E, 1998) (https://kascomarine.com/blog/the-fluidity-of-evaporation/)

These are surface aerators operated by a propeller, and water is sprayed into the air from the center of the float through an opening. The entire equipment is suspended just below the surface of the water with the help of the float. The float in the component of the vertical pumps must have in its component two anchor points to maintain stability and to prevent the rotation of the unit during operation. The anchoring is done with the help of cables fixed to the edge of the pond or to a heavy object on the bottom of the pond. This type of aerator does not circulate the water in the pond, so that difficulties may occur in the total mixing of the thermal stratification, and the lower layers remaining anoxic. That is why these vertical aerators are used exclusively in shallow ponds for trout and tilapia crops. The minimum operating depths vary from 53 to 122 cm, depending on the pumping efficiency and the size of the unit. (worldfishcenter.org)

PADDLE WHEELS

This aeration equipment is generally of two types: aerodynamic with paddle wheels and floating electric aerators. The electric aerator with paddle wheels is conditioned by the availability of electricity in the aquaculture pond. Electric paddle aerators are usually mounted on floats and anchored on the shore of the pond. The paddle wheel of such an aerator helps to spray water into the air to increase the aeration rate.

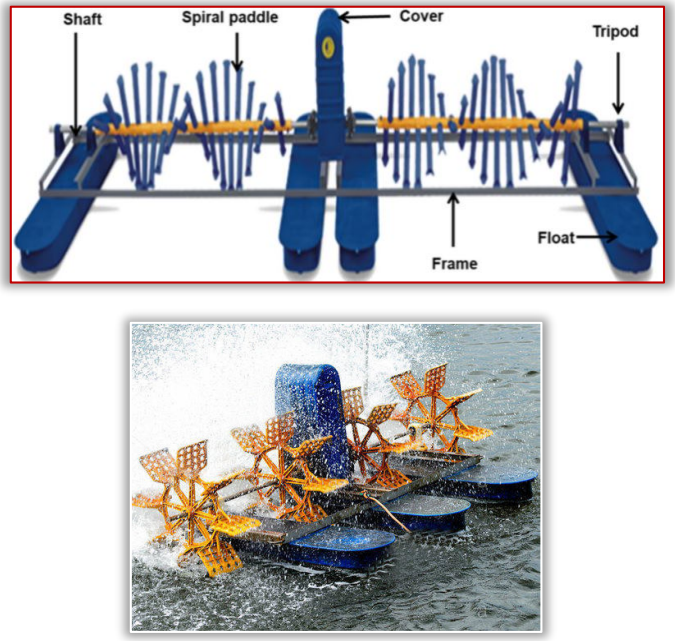

Figure 3 –Designs of paddle wheel aerator (Subha M. Roy 2021; https://www.indiamart.com/proddetail/aquaculture-paddle-wheel-aerator-20206411230.html)

This aerator model is composed of a frame, wheel with blades and bearings, floats, motor, speed reduction mechanism and coupling. Pallet aerators are the most common types of aerators used in large ponds, and the paddle wheel or their rotor is made mainly of polyvinyl chloride (PVC) or stainless steel, and PVC floats (Ahmad T. and Boyd C.E, 1988).

The motor is connected to a gearbox to reduce the speed through a shaft, coupling and bearings. Several wheels are connected to the shaft, and the engine and gearbox are positioned in the center of the frame. The whole assembly is fixed on the frame, and the frame is mounted on two floats.

The floats are designed so that the rotors of the paddle wheels are partially submerged. Rotating the blade on a vertical plane helps to release water into the atmosphere to absorb oxygen from it to increase the DO content of the water. Increasing the DO content of water and throwing water into the atmosphere to absorb oxygen from it is done by rotating the blade on a vertical plane. PTO-powered paddle wheels for tractors usually have a very high power and can have standard oxygen transfer rate (SOTR) values of 40 kg O_2 / h or higher).

These types of aerators are very effective when an acute lack of DO concentration is detected in the pond water. Due to the fact that most tractors have a much higher power than would be necessary in the operation of an aerator, a large fraction of the available power is lost, and therefore the aeration efficiency is very low.

These types of aerators are very useful in case of emergencies, because they can be moved quickly and easily to the place of need, and in most cases, wheels with paddles operated by PTO usually have a paddle immersion of 75 to 100 mm (Roy Subha M, 2021).

Ahmad T. and Boyd CE 1998 did research and found that the most suitable design for the electric aerator, which forms an interior angle of 135 degrees in cross section.

DIFFUSE AIR SYSTEMS

Diffuse air systems have a high-volume blower that acts at low pressure to supply air to speakers that are suspended in water or are located at the bottom of the pond.

The types of diffusers used in the component of diffuse air systems are varied and are made of various materials, these can be: porous ceramic tubes, perforated plastic pipes, ceramic dome diffusers, perforated rubber tubes or porous paper tubes. The location of these diffusers on the bottom of the pond contributes to the minimization of the suspended sediments in the pond. (Boyd C.E., 1998)

The minimum allowable pressure of a diffuser air system becomes higher as the water depth above the diffusers increases, as there must be sufficient pressure to force air through the duct system and to cause air to exit the diffuser against hydrostatic pressure at the discharge point.

Figure 4 – An air diffuser pond/tank aerator in operation (worldfishcenter.org)

Diffuse air systems that release small bubbles are usually more efficient than those that discharge coarse bubbles. This is because the fine bubbles have a larger surface area for the surrounding water than the larger bubbles. Oxygen diffuses into the water to the surface, so a large surface area facilitates more efficient oxygen transfer (Boyd C.E., 1995).

The depth of the diffuser also has an impact on the water circulation rates in the pond. As the bubbles rise to the surface and expand, water is entrained. This process creates a lifting air, which pumps bubbles and entrained water to the surface. Deeper water is usually colder and denser than surface water and spreads slowly and moves away from the column of growing bubbles, creating a vertical circulation.

The growth of the aquaculture sector will affect water quality by increasing nutrient loads, and high turbidity to chemical discharges, such as drugs and biocides. Increasing nutrient loads can lead to eutrophication of the pond water, and this process can cause the death of crop species, as well as the deterioration of water quality (Duff A, 1987).

Different types of microorganisms, such as bacteria, viruses, algae, fungi and parasites, can be present in effluents from the aquaculture sector and can create negative effects on health, when they are spread and come into contact with humans and other organisms in the environment.

Another negative aspect on the environment is the overfeeding of fish and marine life. This circulation cell has a limited horizontal extent and therefore diffuse aeration systems usually require several diffusers arranged in a network pattern to effectively ventilate and circulate the blockage. These aeration systems are more efficient in deeper ponds and are less common in commercial aquaculture ponds (Perry L. Oakes et al., 2011).

THE IMPACT OF AQUACULTURE ON THE ENVIRONMENT

Despite the benefits that the aquaculture sector offers, such as providing food and creating millions of jobs for the population, this activity also causes a negative impact on the global environment (Martinez-Porchas M., 2012).

The lack of a feeding plan combined with the lack of light can have negative consequences on the environment. Nutrients that remain unabsorbed by marine life are released into the environment and cause pollution of ponds in aquaculture. The food management program that aquaculture producers follow is absolutely essential because it is correlated with economic and environmental sustainability (White, 2013).

Aquaculture, like any other production activity, generates solid waste, such as uneaten or spilled feed and fish feces, as well as dissolved waste, especially carbon, nitrogen and phosphorus, together this waste reduces the quality of the water in the pond.

In flow systems such as ponds or cages, an artificial channel is created by continuously pushing water through the system to maintain a higher water quality for fish, constantly providing them with fresh water (Aero-Tube, 2014).

Urgent measures are needed to manage water quality and the negative impact on the development of this important sector on the environment. In this regard, worldwide, the competent institutions have imposed increasingly stringent standards and regulations for the discharge of effluents from aquaculture (Jegatheesan V., 2011).

CONCLUSIONS

Dissolved oxygen is the most important element concerning water quality in any aquaculture system, because all aerobic aquatic organisms need a constant supply of oxygen to survive.

Aeration equipment is used to increase productivity in aquaculture ponds, therefore understanding the mechanisms of oxygen production, transfer, and depletion is necessary to help pond operators in managing fishing development.

This document provided information regarding dissolved oxygen dynamics related to pond aerators and a brief description of the most widely used aeration technologies in fish farming.

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[1.]Arinola Bola AJAYI, [1.]Ademola Abiola AKANMU

DEVELOPMENT OF A RENEWABLE ENERGY POWERED AVIAN PEST SCARER

[1.] Mechanical Engineering Department, Faculty of Engineering, University of Lagos, Lagos, NIGERIA

Abstract: This paper developed a renewable (solar) energy powered avian pest scarer also known as scarecrow. Flocks of birds are known nuisance for grain crops farmers everywhere from time immemorial. Sometimes, these flocks of birds are often times very small, many in number, from different colonies, and easily habituate to stationary scarecrows. In some areas, human scarers are employed and stationed at ripening grains fields to scare away flocks of birds from feeding on ripe grains. This is usually time consuming and energy sapping. Scarecrows (stationary human effigies) are old ways for scaring away flock birds from grains crops farms without human intervention but the birds soon get used to them (habituate) and even use them as landing pads eventually. The effectiveness of a scarer depends on the conditions under which they are used, the technology employed and the types of flock birds involved. Scarers that are human beings like with irregular motions in the air that cannot be habituated by flocks of birds gives best results. Although, habituation by some bird species may be inevitable thereby diminishing the time of effectiveness of the scarer on the field. It is this challenge of habituation essentially that informed the development of this instant pop-up model to achieve maximum efficiency. A renewable energy powered avian pest scarer that is humane, environmentally friendly and not habituatable to avian pest is developed. It consists of pop-up scarer, an axial fan blower that is powered by batteries which is always charged back with the power from the sun through Photovoltaic (PV) modules and a motion sensor that usually senses the presence of birds before they land and activates the scarer in a panic motion. The scarer is made to pop-up and flutter in the air immediately the sensor detects flocks of birds, so as to be more effective in scaring the intruders, so that the birds do not land. It is effective in scaring stray and flocks of birds because of its sudden pop-up whenever it senses the presence of birds.

Keywords: Avian Pests Scarer, Grain Crops Farmer, Habituate, Renewable Energy, Scarecrow, Solar PV Modules

INTRODUCTION

Flocks of birds are one of the most challenging animals to keep out of agricultural grains fields and can also transmit diseases to foods. Farmers especially grain farmers can face significant financial loss due to pests' damages especially from avian pests (birds). Airports situated away from urban centers do have issues with flocks of preys which can cause problems for aeroplanes during take-off and landing as well (Wells, 2021). There are several means of dealing with or keeping away flock bird pests from desired locations especially grains farms. They can be dealt with chemically or physically. Chemicals such as Dichloro Diphenyl Trichloroethane (DDT) can be dusted on the fields by farmers to kill pest birds but it has been discovered to be harmful also to human beings as well (Haywood, 2021). Colored tapes can also be hung to reflect sunlight to the birds (Schipper, 2021) but when there is no sun or wind, it may not be as effective against the flock birds. VHS tape can be used too, it will produce a humming sound when there is breeze, it is effective when there is wind or breeze (Herlsey, 2019) but when there is no breeze or wind, it may not be effective. The best way to control major avian pests from farms and minimize damages to crops is by dispersing these pests (birds) in a safe and environmentally acceptable way is through the use of scaring technology (Agricultural Board Control, 2021). Objects can be made to resemble humans which are termed "scarecrows" to scare away flock birds. Scarecrows have been in use for a very long time to ward off flock avian pest. Rurals dwellers had invented the use of scarecrow as part of their traditional lifestyle to keep of avian pests.

Historically, in the olden days, the Egyptians, the Greeks and even the Romans all used scarecrows to protect their fields (Darrel, 2018). Immigrant German farmers in the United States made scarecrows looking like humans called "bootzamon," but later changed to "bogeyman". Many works had been carried out on scarecrows in the past. The traditional scarecrows are stationary, constructed to resemble humans in grains fields that are about to ripen, to scare away flocking birds from feeding on the field. (Lorimer, 2013) but in most situations, these traditional scarecrows and models are not alarming or threatening to birds to deter them from landing in the farm (Inglis, 1980). Howard et al. (1985) proposed models that can be active with sound and motion when flock birds are sighted but stops immediately when the birds leave which will make the birds not habituate to the model easily and fast. Sekhar (1998) showed in a study that nearly 50% of the households in the villages studied in their article had evidence of crop losses due to animal invasion. Richardson et al. (2014) assessed the effectiveness of an electronic scarecrow on 4 mammalian crop-raiders in Limpopo province of South Africa. They installed the electronic scarecrows farms and discovered that electronic scarecrows are useful weapons to mitigate human-wildlife conflict. Goboshoa et. al (2015) conducted a study to establish the types of wild animals feeding on the agricultural fields' crops and estimated the losses due to these animals. Different methods were used to analyze the data collected through semi-structured questionnaires, focus group discussion, direct observation and key informant interview. Saha et al. (2017) focused on different scientific applications which will result in better accuracy and results oriented remote agricultural fields monitoring

with less human-power. Pandapotan, and Silalahi (2019) traces various forms of local wisdom as social capital for paddy rice farmers in Deli Serdang District and related the concept of sustainable development where the emphasis is on economic growth and socio-cultural factors which can lead to the beneficial use of the environment. Inglis (1980) tested a model of scarecrow made in the likeness of human being with head and its raised hands moving at time intervals. The movements give alarming and scaring scene situations which is better than unanimated models but the birds got habituated to it. Achiron (1988) developed an inflated human effigy scarecrow placed on a 3- wheeled cart that is guided along cables in fields and orchards. However, scientific studies have not proven its efficacy on any species of birds. Beringer, et. al (2013) evaluated scarecrow that is activated by animals and a monofilament fence to reduce deer intrution into fields planted with soybean. The effectiveness of the animal-activated scarecrow (AAS) was evaluated and discovered that deer were habituating to the devices and concluded that AAS will be effective as short-term deterrence for deer in a small area. Haque and Broom (1985) carried out experiments comparing the use of kites as scarecrow and gas banger sounds to scare off woodpigeon from damaging crops and observed that damages in crop fields with a gas banger sound exceeded those in fields with a kite and concluded that kites can be more effective in reducing damage by woodpigeons if the kites can be activated mostly in mornings because habituation of the pigeons to the kite was not noticed. Cummings et. al. (1986) evaluated a combination of Purivox® Double-John carousel propane exploder and CO_2 pop-up scarecrow operated in unison in a field of ripening sunflower. It was discovered that during the first 10-day cycle trials, damages on three of the fields were reduced to a mean of 84%, while in the second cycle trials, damage was reduced further to an average of 59%. Pornpanomchai et al. (2011) developed a computer software system that can drive away birds from a farm by detecting pest birds in real time through a video frame and then generates a loud sound to drive the birds away. Brown and Brown (2021) evaluated a moving green laser beam (light) to control and scare away birds from sweet corn field and discovered that automated laser scarecrows reduced damage done by birds to sweet corn under field conditions. Mog (2017) constructed a non-harmful animal scaring system to protect a plantation farm from harmful animals with smart phone application. The system is controlled remotely by a smart phone which sets up devices such as a scarecrow balloon, an audio system and light lamps. This set up was successfully applied to a watermelon and a cabbage farm field for two years and no damage was recorded. Alneimi et. al. (2019) proposed the conversion of the traditional scarecrows to multi-function e-scarecrow (MFeSC) to perform more than one function at the same time. They suggested that MFESC should consist of sensor which will detect the sounds from intruding birds, and also an indicator to measure temperature and humidity of the farm. They suggested also that the scarecrow should contain some pieces of clothes that should be moving whenever the device senses the birds in the designated areas and should also produce noise and lightings to scare and keep birds away. Sakhare et.al. (2012) designed a cost-effective Intelligent Video Surveillance remote farm monitoring system for Indian Farms. The system will observe the intruders in the farm and force the intruder to leave the farm by initiating alarm and light to scare the intruder away. Tendolkar and Ramya (2020) proposed a solution named "CareBro" that is design to manage a farm autonomously and remotely without physical presence. The carebro is to interact with the smart farm devices in an IOT environment. The CareBro is connected to the farmer through the cloud computing, with real time monitoring and decision making thereby ensuring the perfect farm management solution in urban, rural, largescale and small-scale farmers. Roy et al (2021) proposed a pest bird-controlling protocol which is based on the use of unmanned aerial vehicle (UAV). The UAV is to reduce the request serving delay significantly due to the aerial communication mode. A detailed analysis showed the effectiveness of this solution compared to known parameters.

Often, however, the old practice of using motionless scarecrows provide only short-term protection or are ineffective in scaring flock birds. Some birds may even utilize them as perches, or associate them with favorable conditions. Flying hawk and owl scarers in some cases can be more effective than motionless scarecrows, because birds can rapidly habituate to their presence (Conover, 1982). Snake and cat scarecrow models are seldom of any value. For best results, scarecrow models should be moving irregularly, be highly visible, and be moved frequently at the site to help alleviate habituation. Dangling streamers or reflectors from scarecrows and using brightly colored loose clothing will help increase their effectiveness because they move in the wind and birds react more readily to colored and moving objects. A scarecrow that can be a good catch for farmers. Either small- or large-scale farming must be effective, affordable, environmentally friendly, autonomous, simple and scalable. The objective of this paper is to develop an inflatable renewable energy (solar) powered avian pests' scarer (scarecrow), using brightly colored loose clothing materials that will be moving which will increase its effectiveness which is effective, affordable, environmentally friendly, autonomous, simple and scalable. This will reduce financial loss due to grains crops damages caused by flock birds, and offer reliable, humane and safe agricultural bird dispersal practices. An inflatable scarecrow is an electrically operated/controlled scaring device based on the traditional scarecrow, operating electrically and recharged from a solar powered source. This scarecrow is one of the most effective ways of scaring away unwanted avian pests from the farm even before they land on the farm to feed. The inflatable

scarecrow has been a reliable device used in scaring away pest since it inflates automatically when it senses any foreign enemy (human, pest). It also creates an environment appearing hostile to birds and it is difficult for birds to habituate in such situations because the birds will not able to adapt to non-random movement of the multi-color effigy.

MATERIALS AND METHODS

— Materials

The essential materials used for this project are solar (PV) panels, Charge Controller, Batteries, Motion Sensor, scarer, axial blower fan. Each of these items are discussed below.

≡ Solar Panels

The solar photovoltaic (PV) panel, Figure 1, was used to generate the electrical energy required for the operation.

Figure 1: A Solar Photovoltaic (PV) panel

≡ Charge Controller

A 12 V/24 V 30A charge controller shown in Figure 2 was used to control the charging of the battery so that it is overcharged or over discharged. Whenever the battery is fully charged, the charge controller stops the changing process of the batteries and feeds the load unit directly. This charge controllers have one-way diodes installed in it, that prevents backflow of current from the battery back to the solar panels at night when there is no charging from the solar panels. These makes the battery retains its charge overnight.

Figure 2: A PWM Solar Charge Controller

≡ The Battery (Rechargeable, Deep Cycle)

The battery shown in Figure 3, also known as accumulator is a device for storing electrical charges for later use. The battery acts as a storage device to store over excess charges and as stabilizer to smoothen out the weather dependent electricity generation during fluctuation. The batteries used for this set-up are 12 V deep cycle rechargeable batteries because they have the capacities to charged and discharged in several thousand cycles in their life time.

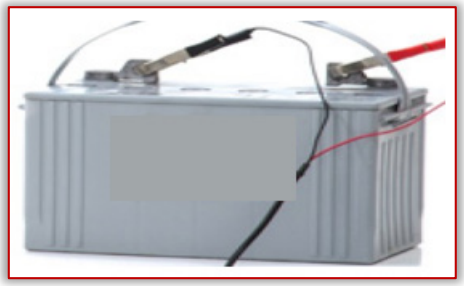

Figure 3: 12 V non-spillable Deep cycle Battery

The Motion sensor

A motion sensor shown Figure 4 senses/ detects motions/movements of flock birds from a pre-determined distance of about 30 feet from the field and activates/ triggers the fan blower in the inflatable balloon scarer which prevents the birds from landing in the protected field/farm. The birds cannot habituate to the scarer.

Figure 4: A Passive infrared (PIR) motion sensor used

The motion sensor used for this work uses passive infra-red (PID) technologies to detect movement in the covered area. It has a thin pyroelectric film material that responds to infra-red radiation by emitting electric current whenever motion is detected. It can detect objects at a distance of 30 feet in an arc of 140° whether during the day or at night depending on the settings and it has adjustable time duration of between 5 seconds and 5 minutes to work before stopping. This sensor has an operating current of 14 micro amperes (14 μA) and an operating voltage of 12V. Therefore, its power consumption is 0.000168 W (0.168 mW). The Sensor has two (2) controls which allows the sensor to be tuned to any settings for Delay Time and Lux. The "Delay Time" is the response time to trigger off the axial fan blower after detecting motion. The Time dial indicates the length of time that the sensor will stay on after it has been triggered. The Lux dial indicates the light level during which the sensor will become operational. Sensor can operate at dark or/in the day light depending on the Lux settings.

≡ The motor (inflatable scarecrow blower)

The inflatable scarer is composed of a thick, strong vinyl and nylon; therefore, it is being inflated using an electric powered fan blower. An external rotor fan unlike conventional motors whose rotors are on the inside of a wound stator is employed. An external rotor principle leads to small efficient motors, ideal for saving space. This presents

unique advantages to the fan and user in that it is extremely compact, therefore saving space, the hub and impeller becomes one integrated unit of short axial length which assure precision balancing, heat generated by the fan motor is effectively removed by the airstream, since the fan impeller acts as a rotating heat sink, speed control is possible but the fan is set to the highest speed for maximum effectiveness. The fan blower used in this work is a 12 V dc blower shown in Figure 5. The scarer will keep flying as long as the blower is working. A centrifugal fan was used because of its ability to develop pressure in a ducted air system. The blower has a housing that collects or gathers the air as it is expelled from the rotor and directs it out in a single stream into the inflatable scarer thus keeping it inflated. The blower used for the construction of this project is rated at 12 V, 4.5 A and a power consumption of 54 W.

Figure 5a: Image of a blower

Figure 5b: A Centrifugal ducted fan

≡ Inflatable scarecrow

The inflatable scarecrow is composed of thick, strong vinyl and nylon; therefore, it is inflated using an electric powered fan blower. When inflated, it stands in the air waving and mimicking a panicking human being. This situation creates fear in the flock birds and they cannot habituate this kind of random motions. Principle of constant leakage is employed with small punctures made at the edges of the inflatable scarer to allow air being blown by the fan blower to escape.

— Methods

≡ Design considerations

This section discusses the sizing of various components used for the set-up of the renewable energy powered avian pests' scarer.

✓ Solar power requirements.

There are some basic things to consider when creating a solar system set up. These include radiation insolation in the area of deployment, how much energy load would the appliance use over a period of time? How much energy can the solar panel generate over a period of time? Is the energy going to be stored and storage capacity of the battery?

✓ The appliance (Load)

The intended purpose of the scarer is to scare away birds, pest and other unwanted animals. Using the birds as the key subject. According to the research conducted on birds by a volunteer's research community (RSPB community), it was discovered that birds mostly come out to raid farms twice a day. They come out in the morning around 9 am to 12 pm, to roost and look for natural food which is a period of about 3 hours and also in the evening around 3 pm to 6 pm which is another 3 hours for feeding. So, if intended hours of use is assumed to be 6 hours, therefore, the 54 W blower which is the only electrical load since the load of the sensor is negligible compared to the overall ratings. The 54 W rotor working for a total of a period of 6 hours, will consume 54 W x 6 hours = 324 Wh of energy per day. If factor of safety of 20 % is allowed for the system, the total energy requirement will be 324/0.8 = 405 Wh.

Therefore, the energy requirement is = < 405 Wh.

✓ Battery storage Design

The battery capacity is measured in Amp hour (Ah) and Energy requirement is given in watt-hour, therefore, to convert Wh to Ah, we divide energy (Wh) by the voltage of the battery (24 V) to get Ah. The energy required = 405 Wh

Storage required i.e., battery capacity required = 405 Wh/12 V = 33.75 Ah.

If 80 % discharge is assumed, the battery capacity required will be = 42.1875 Ah.

A battery of minimum capacity of 40 Ah will be required. Four numbers of 12 Ah, 12 V batteries were connected in parallel to form a total 48 Ah at 12 V = 576 Wh.

✓ Solar panel Sizing

The sizing of the solar panels' capacity will depend on the insolation (average daily sun hours) in the area. The power generation rating of a solar panel is also given in watts. In theory, to calculate the energy it can supply to the battery, multiply watts (of the solar panel) by the hours exposed to sunshine.

The deployment is at Agbowa, Lagos, the average daily solar radiation is 5. 22 kWh/m^2/day (PV Watts) (National Renewable Energy Lab. (2021)).

The load required is = 576 WH = 0.576 kWh/day.

The solar power requirement is 0.576 kWh ÷ 5.22 kWh/m^2/day = 0.1103 m^2 at standard condition of 1000W/m^2 and T_c of 25°C.

The wattage of the solar panel = 0.1103 m^2 x 1000 W/m^2 = 110.3 W.

Two 55 W solar panels were selected and connected in parallel giving 12 V output with the following specification: Rated power of 55 W, rated voltage of 18.0 V and rated current of 3.06 A.

Open circuit voltage is 22.0 and short circuit current is 3.42 A. Photovoltaic rated at 1000 W/m^2, solar irradiation AM = 1.5 at 25^{0}C cell temperature.

≡ Experimental Set up

After obtaining all the required sizes of the various components needed for the scarer, the whole components were set up as indicated Figures 6 & 7. The motion sensor senses the presence of a bird or flock of birds and sends signal to the rotor of the fan blower which blows air at a very high speed and high pressure to jack up the inflatable scarecrow suddenly. The inflatable scarer jumps up waving in the air in a panicking mode with irregular motions that cannot be predicted.

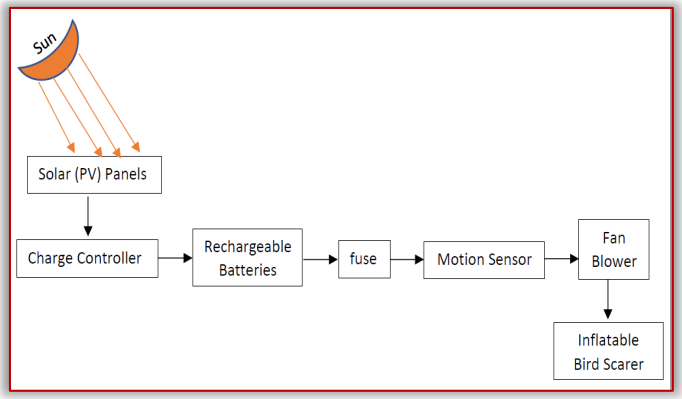

Figure 6: The block diagram set-up of the renewable energy avian pests' scarer

Figure 7: The set-up of the renewable energy avian pests' scarer

DISCUSSION

The components were set up as indicated in Figure 6. The sensor is positioned to capture objects of approach. Immediately, the object of approach is within 30 feet of the sensor, the inflatable scarer jumps up and started panicking motions in the air (Figure 7). The motions stopped after 120 seconds of inactivity. This invention is able to scare away flock birds and any avian pest.

CONCLUSIONS

Renewable energy powered avian pests' scarer was developed. A passive infra-red motion sensor was used to detect the approach of pest flock birds which normally triggers the inflatable scarer to jump up into panicking motion in the air to scare away the birds. The birds were not be able to habituate to it because of the unpredictable motions of the scarer and life like reactions to the bird approaches.

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[1.]Bogdan MARIĆ, [1.]Vlado MEDAKOVIĆ

DESIGN OF WORKING UNITS IN THE MANUFACTURING SYSTEM OF TOOL MACHINES REPAIR

[1.] University of East Sarajevo, Faculty of Mechanical Engineering East Sarajevo, East Sarajevo, BOSNIA & HERZEGOVINA

Abstract: The paper investigates the possibility of applying the concept of production on the principle of the group technology. To make that possible, it is necessary to have a stable production program as one of the most influential factors in the choice of spatial structure. The following factors have been observed: the process of grouping parts of machine tools in the overhaul by applying the classification system and subject approach in the construction of production structures. Empirical research has been related to the classification and categorisation of parts - production programs. In the second phase, the analysis of classification and operational similarity of parts in the machine tools overhaul process has been performed. The third phase has been related to the analysis of the representation of operational groups of individual machine tools in relation to the total number of formed operational groups in the machine tools overhaul production system. Research has shown that there are certain laws in the formation of operational groups, which can reliably assess the impact of analysed factors on the formation of permanent work units in terms of equipment allocation and workplaces (layout) regardless of the introduction of different types of machine tools in the overhaul process, and that has enabled the overhaul process efficiency increase in the overhaul system.
Keywords: group technology, work unit, overhaul, machine tool, layout

INTRODUCTION

Today, the problem of increasing the efficiency of the machine tool overhaul process is given extraordinary attention. The reasons for that should be sought in the fact that machine tools form the basis of the production process in the metal industry. Their overhaul represents an unjustified cost for both users and manufacturers. Therefore, ways are being sought to reduce these costs, i.e. to increase the efficiency of the machine tools overhaul process.

In this regard, an efficient overhaul, especially its subsystem for the production of parts of machine tools which are in the process of overhaul, requires an appropriate choice of spatial structure. The selected spatial structure directly determines the material flow system, which is reflected in the controllability of production, production cycles and the degree of utilization of means of production [3].

The choice of spatial structure is influenced by a number of factors, the most influential of which are the *production program* and *technology*, i.e. the product assortment and quantities, degree of constructional and technological similarity of products, shape, dimensions and tolerances, rate of product changes, market life cycle etc.[3].

On the basis of the above mentioned, the main goal of restructuring the existing spatial layout, in our case that is the machine tools overhaul production system, has been to explore the possibility of applying the concept of production on the principle of so-called Group technology - creation of work units (cells). This solution attempts to modify the traditional layout according to the process, by using all the advantages of line production [8]. To make it possible, it is necessary to have a stable production program, as mentioned earlier, as one of the most influential factors in the choice of spatial structure.

The basic *hypothesis* in this paper is derived from the stated and reads: *By applying the group technology, i.e. the classification system to the production program of the machine tools overhaul production system, it is possible to obtain a stable production program in the form of a finite number of operational groups.*

We will prove this hypothesis by the fact that the application of group technology, i.e. of the classification system on the production program of the machine tools overhaul production system, can lead to the formation of a finite number of operational groups regardless of the introduction of different types of machine tools in the overhaul process.

GROUP TECHNOLOGY

In order to take advantage of batch production and, in some production systems, of individual production, the idea of group technology appeared in the sixties of the 20th century. Group technology is a concept according to which work objects with similar characteristics are grouped into families (groups). The approach is based on integrating the work objects with similar characteristics, on the basis of a classification system that contains the criteria of categorisation into the groups of work objects with similar technological characteristics. A group of work objects obtained in the mentioned way on a certain work operation is called an *operational group*. It takes place with a certain flow of the production system once or a few times in the observed time period as a function of the type of flow and forms the basis for designing the group flow of the work process. The goal is to facilitate the processes of design - construction, development of technological processes and design of production structures.

Grouping procedures enable visible reduction of technological work, organisation of material flows, easier control of data flows and bases, directing the work of technologists, constructors, planners and flow controllers to the operational group as the basic unit of the system, thus achieving significant output effects.

The basis for setting up of a grouping system is the system of classification, i.e. of the categorisation of the work objects of the program in question into groups, where this term implies a system which sets out the conditions of classification. The classification process basically consists of the division of the basic set into subsets according to certain characteristics and is essentially a decision-making process aimed at shaping the subsets according to the requirements of the technological process.

The implementation of group technology requires the construction of a system of classification of parts, on the basis of which the grouping into families is performed. The classification is performed according to the technological-constructive characteristics of the elements and with the help of the classification system, whereby the necessary information is obtained by linking individual codes or their combinations to the individual parameters of the elements. Which parameters of the elements will be taken into account in the classification and how the classification system will be developed depends on the constructive characteristics of the elements and on the type of technologies by which the elements are formed.

The classification can be performed even a step further by organising the equipment and workplaces in production according to the family of parts. In this case, all the necessary equipment is grouped to produce a certain family of parts, thus achieving a proper line flow. When a family of similar parts is produced in a work unit, some equipment (machine) can be duplicated from one work unit to another and the capacity utilisation can therefore be reduced more than with the alternative or mixed flow. Nevertheless, the overall benefits of group technology are significant, provided that the optimal number of parts can be covered in each work unit.

The practical application of group technology has two basic steps:

- identifying and defining the family of parts - *operational groups* and
- organisation of production equipment and jobs into appropriate *work units* (cells).

WORK UNITS

Machines (classical or numerically controlled) are grouped in a work unit in accordance with the production process of a group of technologically similar work objects. The internal structure of a work unit (cell) is similar to the division on the basis of the type of processing, which has the flexibility of such a structure, but with a spatial arrangement which best suits the flow of production process materials for a defined product group. Due to that, the production system, consisting of work units, possesses the line efficiency and partially the flexibility of systems structured according to the type of processing. This structure also contributes to the humanisation of work, as it allows the workers an insight into the entire production process, or the end result and purpose of their work. Therefore, the workers can perform a part of the organizational work, and that reflects in the increasing of motivation and achieving of better work results.

Structuring of a system into work units results in the division into smaller subsystems, and that significantly simplifies the material flow system, as well as the production planning and control. Therefore, they are particularly suitable for the application of the group technology concept and production automation.

Work units can be completely independent, implying that they can fully process a group of similar products from start to finish. Then there will be no flow of material among the work units in the system, but it will take place mostly only with the warehouses.

If for a given group of products and production quantities the load of some, especially expensive means of production is small, it is not profitable for economic reasons to provide such capacities, but they should, if possible, be shared with another work unit. Work units that share the means of production with other work units are called partially independent and cause a mutual flow of materials.

The basic characteristics of production in work units are [8]:

- shorter transport routes and less material handling than with layouts based on the process,
- shorter ordering time,
- reduced retention time of individual parts in the process by up to 80% compared to classic workshop production (smaller quantity of unfinished production),
- reduced amount of material in intermediate warehouses in relation to the schedule based on the processing process,
- better motivation of workers leads to increased productivity,
- simplified planning and production control,
- preparation time is reduced so that the batch replacement costs are lower (shorter preparatory-ending time).
- shorter waiting time of parts to be processed in relation to the production based on the processing process,
- reduced amount of scrap,
- better utilization of work surfaces leads to reduced investment costs for the building (up to 20%),
- more favourable use of equipment than in line production,
- relatively high productivity,
- large investments.

METHODOLOGY

In this paper, the emphasis is placed on a research in terms of identifying and defining the family of parts - operational groups and the laws of formation of operational groups by introducing different types of machine tools into the overhaul process. For that purpose, the classification system KS-IIS-08 and the automated procedure for shaping production structures - APOPS-08 developed at the Institute for Industrial Systems of the Faculty of Technical Sciences in

Novi Sad have been used to classify the replaced parts in the process of overhauling the following machine tools:

1. Radial drill „RABOMA" 12U-1500,
2. Horizontal drilling and milling machine „TOS" HB-80,
3. Short-run planer „PRVOMAJSKA" KB-500,
4. Universal milling machine „PRVOMAJSKA" UG-1,
5. Milling machine for hobbing „TOS" FO-6,
6. Universal production lathe „POTISJE" PA-30.

The replaced parts of these machine tools also make up the *production program* by the assortment (p_j) and quantities (q_j) of the machine tools overhaul production system.

The analysis of the production program consisting of the replaced parts of the mentioned machine tools will be performed using:

1. Coefficient of operational similarity and
2. Coefficient of representation of operational groups.

Ad. 1) The *coefficient of operational similarity* ($K_{op.sl.}$) is a measure of unification of parts during the overhaul of machine tools according to predetermined characteristics and is given in the following form:

$$K_{op.sl.} = \frac{\text{number of operational groups}}{\text{number of different parts}} \cdot 100[\%]. \quad (1)$$

The size of the coefficient of operational similarity is influenced by predefined characteristics according to which the parts are grouped into certain operational groups. The coefficient of operational similarity directly affects the degree of flow seriality and the choice of the type of material flow in the machine tools overhaul production system by increasing the units of work objects with similar characteristics in the production program.

Ad. 2) The *coefficient of representation of operational groups* (K_{zog}) is a measure of the representation of operational groups of a machine tool in overhaul in relation to the total number of formed operational groups in the machine tools overhaul production system and is given in the following form:

$$K_{zog} = \frac{\text{number of operational groups of a machine tool}}{\text{total number of operational groups}} \cdot 100[\%] \quad (2)$$

RESULTS AND DISCUSSION

In the text that follows, there is a presentation of the results of empirical research in terms of:

1. Analysis of production programs,
2. Analysis of operational similarity and
3. Analysis of the representation of operational groups.

Ad. 1) The production program is given in Table 1 in the form of assortment (p_j) and total quantity (q_j). The table shows a large number of different parts, and thus a large number of individual material flows through the machine tool overhaul production system.

Ad. 2) Coefficients of operational similarity for individual machine tools in overhaul are given in Table 2. Through the coefficients of operational similarity, the table shows how much the number of material flows in the production system will be reduced by forming operational groups in relation to individual flows. That percentage of overhaul of one machine tool ranges from 75% to 85,2%. However, by increasing the number of machine tools that are in the process of overhaul, the number of material flows in the production system decreases by 94,3%.

Table 1. Replaced machine tool parts - Production program

Ord. no.	NAME OF THE MACHINE TOOL	Production program	
		Assortment (p_j) [pcs]	Quantity (q_j) [pcs]
1	Radial drill „RABOMA" 12U-1500	189	615
2	Horizontal drilling and milling machine „TOS" HB-80	125	477
3	Short-run planer „PRVOMAJSKA" KB-500	145	261
4	Universal milling machine „PRVOMAJSKA" UG-1	80	212
5	Milling machine for hobbing „TOS" FO-6	92	121
6	Universal-production lathe „POTISJE" PA-30	109	139

Ad. 3) By applying the classification system KS-IIS-08 and the automated procedure for shaping production structures - APOPS-08 to the parts, i.e. the production program for the mentioned machine tools, a total of 42 operational groups has been formed.

The representation of the operational groups of individual machine tools in the total number of operational groups is given, through the coefficient of representation of operational groups (K_{zog}), in Table 2.

Table 2. Values of coefficients of similarity and coefficients of representation of operational groups

Ord. no.	NAME OF THE MACHINE TOOL	Number op. group	$K_{op.sl.}$ [%]	K_{zog} [%]
1	Radial drill „RABOMA" 12U-1500	28	85,2	66,6
2	Horizontal drilling and milling machine „TOS" HB-80	27	78,4	64,3
3	Short-run planer „PRVOMAJSKA" KB-500	24	83,4	57,1
4	Universal milling machine „PRVOMAJSKA" UG-1	19	76,3	45,2
5	Milling machine for hobbing „TOS" FO-6	23	75	54,8
6	Universal-production lathe „POTISJE" PA-30	33	79,8	52,4

Analysis of the representation of operational groups indicates that the representation of operational groups of individual machine tools in the total number of formed operational groups ranges from 45,2 to 66,6%, which indicates a certain consistency of the formed operational groups.

The increase of newly formed operational groups of individual machine tools in relation to the number of formed

operational groups of radial drill „RABOMA“ 12U-1500 is shown in Figure 1.

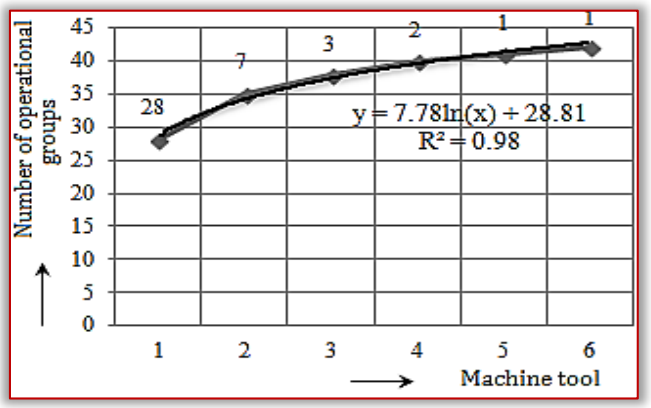

Figure 1. Diagram of growth of operational groups

The representation of parts in newly formed operational groups is:

≡ 12% on the horizontal drilling and milling machine „TOS“ HB-80,
≡ 2,8% on the short-run planer „PRVOMAJSKA“ KB-500,
≡ 3,8% on the universal milling machine „PRVOMAJSKA“ UG-1,
≡ 1,1% on the milling machine for hobbing „TOS“ FO-6,
≡ 14,7% on the universal-production lathe „POTISJE“ PA-30.

From the diagram in Figure 1, we notice the regularity of the growth of operational groups. This regularity leads to the conclusion that there is no significant increase in operational groups, clearly indicating that the established work units in the machine tools overhaul production system based on group technology will not change regardless of the introduction of different types of machine tools in the overhaul process.

On the basis of the mentioned, it can be concluded that the hypothesis of the subject paper has been proven.

CONCLUSION

The research presented in this paper and the obtained results lead to the following conclusions:

≡ The presented grouping procedure and the applied classification system are an objective basis for:
  ✓ development of a flexible machine tools overhaul production system with an increased degree of efficiency based on work units;
  ✓ defining of the scope and structure of overhaul works for certain types and families of machine tools;
  ✓ constructive unification of parts in the process of deffectation;
  ✓ unification of surfaces of parts, materials and semi-finished products.
≡ The developed grouping procedure and the applied classification system are applicable in real machine tools overhaul production systems with the:
  ✓ definition of the machine tools overhaul corpus,
  ✓ definition of the overhaul for certain types and families of machine tools,
  ✓ definition of production and material norms,
  ✓ introduction of a classification-identification system,
  ✓ introduction of an appropriate information system based on computer data processing,
  ✓ introduction of the necessary technological discipline.
≡ Overhaul of capital equipment, such as machine tools, performed in the presented manner, will provide better efficiency in comparison to the previous method of execution.

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[1.]Muofunanya UMUNNA, [1.]Kayode J. SIMONYAN, [2.]Kenechi NWOSU-OBIEOGU,
[1.]Okechukwu ODUMA, [1.]Francis N. ORJI, [1.]Precious O. EHIOMOGUE

CABINET DRYING EFFECTS ON PROXIMATE COMPOSITION OF TWO VERIATIES OF GINGER RYHIZOMS

[1.]Department of Agricultural and Bio-resources Engineering, College of Engineering and Engineering Technology, Michael Okpara University of Agriculture, Umudike Umuahia, Abia State, NIGERIA
[2.]Department of Chemical Engineering, College of Engineering and Engineering Technology, Michael Okpara University of Agriculture, Umudike Umuahia, Abia State, NIGERIA

Abstract: Ginger (Zingiber officinale Roscoe) of two verities {UG I ('Tafin-Giwa', a yellowish variety with plump rhizomes) and UG II ('Yatsun-Biri', a black or dark variety with small compact rhizomes)} were analysed to identify its proximate composition. The effects of drying as a processing technique on ginger were investigated with respect to the proximate composition of the produce. The UG I and UG II were collected, sorted (whole, peeled and unpeeled) and (slice, peeled and unpeeled), and were subjected to Unblanched and Blanched (50°Cat 3,6 and 9minuts respectively) treatments and dried using cabinet dryer for a period of two weeks. The initial moisture content of UG I and UG II were 71.12% and 72.47% respectively, the final moisture content were reduced to 4.99% SP (Unblanched) and 5.02% WUP (Blanched at 3mins) for UG I, while that of UG II were 4.41% SP (Unblanched) and 5.63% WUP (Blanched at 3mins). For Carbohydrate content, 58.74%was the lowest level at Unblanched (Whole Unpeeled), and 67.57% indicates higher CHO content at Blanched 50°Cat 9mins (Split peeled) treatments for UG I samples. Similarly, for UG II, CHO's presence was low at 55.91%for Unblanched (Whole Unpeeled) and high at 75.70%for Blanched 50°Cat 9mins (Whole peeled) treatment. Ash content was observed to be low at 5.47%for Blanched 50°Cat 9mins (Split peeled) and high at 7.59%for Unblanched (Whole Unpeeled) treatment for UG I samples, and 3.86%low for Blanched 50°Cat 9mins (Split peeled) with higher ash content of 7.76%Unblanched (Whole Unpeeled) treatment for UG II samples. UG I and UG II samples determination for Crude fibre was observed at 4.64%for Blanched 50°Cat 9mins (Split peeled) and 7.53%at Unblanched (Whole Unpeeled) treatment, 3.72%Blanched 50°Cat 9mins (Split peeled) and 8.98%at Unblanched (Whole Unpeeled) treatment, respectively. Determination of Fat content, at UG I and UG II samples, it was observed that Fat content are less at 7.56%for Blanched 50°Cat 9mins (Split peeled) and at 3.21%for Blanched 50°Cat 9mins (Split peeled) treatments, respectively. Higher Fat content presences were observed at 9.56%for Unblanched (Whole Unpeeled) and 9.89%for Unblanched (Whole Unpeeled) treatments. Crude protein content shows that its presence was higher at 10.72%for Unblanched (Whole Unpeeled) UG I and 11.96%for Unblanched (Whole Unpeeled) treatment UG II. In comparison, it was less at 8.23%Blanched 50°Cat 9mins (Split peeled) UG I and 6.13%Blanched 50°Cat 9mins (Split peeled) treatment UG II. The Cabinet drying is effective in sufficient moisture removal and also for the enhancement of some nutritional composition of the produce (ginger ryhizoms).

Keywords: drying, ginger, proximate, composition, blanched, unblanched

INTRODUCTION

Ginger (Zingiber officinale Roscoe) is an herbaceous perennial crop, grown as an annual crop for its spicy underground rhizomes. The plant has fibrous roots that emerge from the branched rhizomes. Closely grouped, unbranched, pseudostems or overial shoots are produced from the rhizomes. The pseudostems reach a height of 50 - 120cm. The simple, lanceolate, and smooth leaves are alternate and about 25cm long. Ginger is asexually propagated from portions of the rhizome. The flowers of ginger are usually sterile and rarely set seed (Valenzuela, 2011). The shoot, leaf and the stem emit pleasant aroma. The anchorage roots are succulent and when squeezed exude appreciable fluid and emit aroma similar to the one from the other plants parts (Okwuowulu and Ene, 1988; Onu and Simonyan, 2015).Over 25 varieties of ginger are grown worldwide. Varieties differ in the size of the rhizome, flower, aroma, pungency, colour and fiber content (Valenzuela, 2011). Nigerian ginger is darker in colour, minute in size and has more pungent taste when compared to others. Cochin ginger is usually larger, well scraped, contains more starch and breaks with a shorter fracture. African ginger is darker in colour, more pungent in taste and has less flavor than Jamaica ginger (Ghosh, 2011). Two main varieties are grown in Nigeria. Umudike ginger I (UG I) known as the "black yellow ginger" and Umudike ginger II (UG II) known as the "black" ginger. The stem cluster of the yellow ginger is fat and robust, resembling the elephant's foot hence the name "Taffin-giwa". Similarly, the black ginger because of its shriveled and slander nature typical of the monkey's finger, it is called "Yatsun biri" (Okwuowulu and Ene, 1988; Onu and Simonyan, 2015).

NUTRIENT/METABOLIC CONSTITUENTS OF GINGER RHIZOME

Fresh ginger contains 80.9% moisture, 2.3% protein, 0.9% fat, 1.2% minerals, 2.4% fibre and 12.3% carbohydrates *(Hoffman, 2007)*. The minerals present in ginger are iron, calcium and phosphorous. It also contains vitamins such as thiamine, riboflavin, niacin and vitamin C. The composition varies with the type, variety, agronomic conditions, curing methods, drying and storage conditions *(Hoffman, 2007)*. The branching fleshy rhizome composed of 40-60% starch, 10-40% yellow colour volatile oil responsible for its flavour and the remaining percentage for protein, mineral matter and

fiber content (*Simonyan et al., 2003)*. Table 1 comprises of the nutrient/metabolic content of freshly harvested black and yellow ginger rhizome.

Table 1: Nutrient/Metabolic Constituents of Freshly Harvested Ginger Rhizome

S/N	Nutrient/Metabolite	Yellow (Tafin Giwa)	Black (Yatsun biri)
1	Moisture (g/100g)	78.00	80.90
2	Starch (g/100g dry weight)	55.8	57.19
3	Total reducing sugars (g/100g dry weight)	4.80	3.68
4	Crude protein (g/100g dry weight)	17.15	10.15
5	True protein (g/100g dry weight)	3.18	1.84
6	Total free amino acids (g/100g dry weight)	5.27	4.38
7	Crude fiber (g/100g dry weight)	3.24	4.77
8	Total lipids (g/100g dry weight)	2.74	3.61
9	Total ash (g/100g dry weight)	7.75	7.35
10	Acid –insoluble ash (g/100g dry weight)	2.00	2.00
11	Total carotenoids (mg-carotene/100g dry weight)	6.64	5.41
12	Ascorbic acid (g/100g dry weight)	1.23	1.30
13	Ginger oleoresin (g/100g dry weight)	5.61	6.26

Source: Njoku et al. (1995)

The main objective of this research is to determine the effect of Cabinet drying on proximate composition of two verities of ginger rhizomes (UG I and UG II), for Blanched and Unblanched treatment. Proximate analysis is referred to as the partitioning of compounds in a feed into six categories based on the chemical properties of the compounds.

The six categories are moisture, ash, crude protein, crude lipid, crude fibre and nitrogen-free extracts (digestible carbohydrates).

MATERAILS AND METHOD

— Research Materials

A costarred bowl (4 kg) of two ginger varieties, namely Umudike Ginger I and Umudike Ginger II (UG I and UG II), were purchased, respectively from the National Root Crop Research Institute, (NRCRI) Umudike, Abia State, Nigeria. 4 Kilogram of UG I and UG II was cleaned and separated into groups. One of the groups was peeled and splitted with a sharp stainless steel knife. The UG I and UG II split and whole, (peeled and unpeeled) was blanched with the aid of Electric water bath in the Soil and Water Laboratory, Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. Ginger rhizomes were blanched at (3, 6and 9minute), for **50℃,** 0**℃** respectively. Each group with various treatments were subjected to Cabinet drying in sequence. The unblanched UG I and UG II split and whole, (peeled and unpeeled) was also subjected to Cabinet drying for about a period of two weeks, before taken to the laboratory for proximate analysis. All treatments were done at 10mm thickness of UG I and UG II rhizome.

— Chemical analysis

The dried UG I and UG II Samples were subjected to proximate analysis. The proximate composition of the samples UG I and UG II with various treatments, in respect to moisture, protein, fat, ash, fibre and carbohydrate percentage, were determined following the standard methods of association of official analytical chemists (AOAC, 2002).

The UG I and UG II dried samples, were ground into fine powder, using a milling machine. The powdered samples were sieved through mesh 300 μm sieve and stored in air-tight cellophane bag as stock sample in a refrigerator, until required for analysis (Nwinuka et al 2005). Thermal drying method was used in the determination of moisture content of the samples (Nwinuka et al 2005: Ugwoke and Nzekwe 2010).

— Moisture content determination

Moisture was determined by the loss in weight of samples dried with solar and cabinet dryers respectively. The percentage moisture content was calculated by computing the loss in weight on drying as a fraction of the initial weight of sample used and multiplied by 100.

$$\text{Mc}\ (\%) = \frac{\text{Wo}}{\text{Wi}} \times 100$$

where:
Wo = loss in weight (g) on drying
Wi = initial weight of sample (g)

— Crude fat content determination

Crude fat content determination of the sample was done using soxhlet type of the direct solvent extraction method. Crude fat represents total fat in most samples. At the extraction end, the solvent was evaporated and the flask dried in the oven (at 60**℃**). The flask was then cooled and reweighed. The percentage Crude fat (lipid) was calculated using the formula:

$$\text{CL}\ (\%) = \frac{\text{Mex}}{\text{Mg}} \times 100$$

where:
Mex = mass of extract (g)
Ms = mass of sample used (g)

— The Ash content determination

The Ash content was determined using the ignition method by burning the sample in a muffle furnace at 600**℃**for 2 hrs. The percentage ash content was calculated using the formula:

$$\text{Ash}\ (\%) = \frac{\text{Ma}}{\text{Ms}} \times 100$$

where:
Ma = mass of ash (g)
Ms = mass of sample used (g)

— Determination of Crude protein

Determination of Crude protein was done by determining the total organic nitrogen, using the Macro-Kjeldhal method. This involved digestion, distillation and titration. The technique determined the amino nitrogen of the sample, after which the total organic nitrogen was then calculated using the formula:

$$\%\ \text{TON} = \frac{\text{TV} \times \text{NE} \times \text{TVd}}{\text{Ms} \times \text{Vd}} \times 100$$

where:

Tv = Titre value,
NE = mg nitrogen equivalent to molarity of acid,
TVd = total volume to which digest was diluted,
Ms = mass of sample (g)
Vd = volume of digest distilled.

— Determination of Carbohydrate content

Determination of Carbohydrate content of the sample was estimated by 'differences' (Ugwoke and Nzekwe 2010). In this, the sum of the percentages of all the other proximate components was subtracted from 100.

Total CHO (%) = 100 – (**% moisture + % crude protein + % crude fat + % ash**+ % crude fat + % ashotein+ % crude fat+ % ash

RESULTS AND DISCUSSION

— Results

The results obtained in the study and results of the proximate analysis are presented in Table 2.It shows the variation range of values for Cabinet dried samples of UG I and UG II proximate analysis results for blanched and unblanched treatments respectively.

Table 2: Proximate (nutrients) contents of UG I and UG II varieties of ginger rhizome, with various treatments for Cabinet dried samples

	UG I				UG II			
	WP	WUP	SP	SUP	WP	WUP	SP	SUP
UNBLANCHED								
%MC	5.42	5.86	4.99	5.53	5.20	5.54	4.41	4.53
% CP	9.98	10.72	9.82	10.44	8.63	11.94	3.22	11.76
%FAT	8.81	9.54	8.63	9.19	8.78	9.89	8.53	9.63
% CF	6.48	7.53	6.38	7.32	7.15	8.96	7.16	8.89
%ASH	6.64	7.59	6.54	7.42	6.29	7.76	6.38	7.73
%CHO	62.67	58.74	63.64	60.22	63.95	55.91	65.40	57.46
BLANCHED @ 3 MINS								
% MC	5.24	5.02	5.86	5.18	5.94	5.63	6.82	6.71
% CP	8.96	9.38	8.82	8.94	6.87	7.32	6.78	7.21
% FAT	8.34	8.47	8.14	8.35	3.62	3.31	3.53	3.74
% CF	5.27	5.46	5.10	5.36	4.27	4.56	4.17	4.48
%ASH	5.09	6.13	5.77	5.92	4.33	4.60	4.27	4.52
%CHO	66.29	65.54	66.31	66.25	74.97	74.08	74.43	73.34
BLANCHED @ 6 MINS								
% MC	5.77	5.58	6.21	5.66	6.24	5.99	7.21	7.18
% CP	8.74	9.18	8.64	8.75	6.28	7.15	6.42	6.93
% FAT	8.22	8.35	7.97	8.25	3.56	3.68	3.45	3.61
% CF	5.11	5.25	4.88	5.19	4.10	4.37	3.98	4.25
%ASH	5.80	6.02	5.61	5.84	4.17	4.46	4.00	4.33
%CHO	66.36	65.62	66.69	66.31	75.25	74.35	74.94	73.70
BLANCHED @ 9 MINS								
% MC	6.26	6.00	6.48	6.27	6.65	6.49	7.78	7.52
% CP	8.35	8.74	8.26	8.37	6.32	6.86	6.15	6.69
% FAT	7.84	7.97	7.56	7.80	3.39	3.42	3.21	3.33
% CF	4.94	5.03	4.66	4.92	3.90	4.14	3.74	4.02
%ASH	5.62	5.84	5.47	5.63	4.06	4.29	3.86	4.10
%CHO	66.99	66.42	67.57	67.01	75.68	74.80	75.26	74.24

WP – Whole peeled; MC – Moisture content; WUP – Whole unpeeled;
CP – Crude protein; SP – Split peeled; CF – Crude fibre;
SUP – Split unpeeled; CHO – Carbohydrate

— Discussions

The proximate analysis experiment for both UG I and UG II, with various treatments, indicates higher values in percentage for unblanched UG, I, and UG II, the table's result shows increased moisture content, ash content, crude fiber, crude protein, fat, and carbohydrate. While the results for the blanched treatments of UG I and UG II show a reduction in percentage moisture content, ash content, crude fiber, crude protein, fat, and carbohydrate.

The initial moisture content of UG I and UG II were 71.12% and 72.47% respectively, the final moisture content were reduced to 4.99% SP (Unblanched) and 5.02% WUP (Blanched at 3mins) for UG I, while that of UG II were 4.41% SP (Unblanched) and 5.63% WUP (Blanched at 3mins).

For Carbohydrate content, 58.74%was the lowest level at Unblanched (Whole Unpeeled), and 67.57% indicates higher CHO content at Blanched 50℃at 9mins (Split peeled) treatments for UG I samples. Similarly, for UG II, CHO's presence was low at 55.91%for Unblanched (Whole Unpeeled) and high at 75.70%for Blanched 50℃at 9mins (Whole peeled) treatment.

Ash content was observed to be low at 5.47%for Blanched 50℃at 9mins (Split peeled) and high at 7.59%for Unblanched (Whole Unpeeled) treatment for UG I samples, and 3.86%low for Blanched 50℃at 9mins (Split peeled) with higher ash content of 7.76%Unblanched (Whole Unpeeled) treatment for UG II samples.

UG I and UG II samples determination for Crude fibre was observed at 4.64%for Blanched 50℃at 9mins (Split peeled) and 7.53%at Unblanched (Whole Unpeeled) treatment, 3.72%Blanched 50℃at 9mins (Split peeled) and 8.98%at Unblanched (Whole Unpeeled) treatment, respectively.

Determination of Fat content, at UG I and UG II samples, it was observed that Fat content are less at 7.56%for Blanched 50℃at 9mins (Split peeled) and at 3.21%for Blanched 50℃at 9mins (Split peeled) treatments, respectively. Higher Fat content presences were observed at 9.56%for Unblanched (Whole Unpeeled) and 9.89%for Unblanched (Whole Unpeeled) treatments.

Crude protein content shows that its presence was higher at 10.72%for Unblanched (Whole Unpeeled) UG I and 11.96%for Unblanched (Whole Unpeeled) treatment UG II. In comparison, it was less at 8.23%Blanched 50℃at 9mins (Split peeled) UG I and 6.13%Blanched 50℃at 9mins (Split peeled) treatment UG II.

This study's findings agreed with earlier reports on ginger's proximate composition (Nwinuka et al. 2005) and that of phytochemistry and proximate composition of ginger (Ugwoke and Nzekwe 2010).

CONCLUSION AND RECOMMENDATION

The results obtained in this research, can be concluded that the proximate composition for both UG I and UG II, indicates higher values in percentage for the unblanched treatment, which shows increased moisture content, ash content, crude fiber, crude protein, fat, and carbohydrate. While that of blanched treatments, shows a reduction in percentage moisture content, ash content, crude fiber, crude protein, fat, and carbohydrate. The cabinet drying is effective in sufficient

moisture removal and also for the enhancement of some nutritional composition of the produce (ginger ryhizoms).
There is an increase in market demand for good quality dried ginger, hence this study shows that cabinet drying method is suitable for a better end product, which will meet the market demand taking note of the high nutritional components as part of the quality source by customers. Therefore, blanching and cabinet drying at two weeks interval is recommended for post-harvest storage and for ginger powder production because cabinet drying effect enhances its proximate composition.

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[1.]Adriana Elena BOERIU, [2.]Cristina Maria CANJA

APPLICATION OF NEW METHODOLOGY FOR CONTINUOUS IMPROVEMENT IN BREAD MAKING: A CASE STUDY IN ROMANIA

[1.] Transilvania University of Braşov, ROMANIA

Abstract: In the recent decades, it was observed that the usage of lean manufacturing (LM) was increasingly used in production systems. This approach focuses on reducing the manufacturer's fear concerning production system by applying optimal, proven and accessible standard methods that are easy to understand and to apply. The current paper focuses on the application of a series of lean manufacturing tools in one Romanian bread making company. The paper presents the main implementation issues, the obtained results after the application of the tools in the production system. The benefits and improvements were analysed and it leads to continuous improvement and increasing production systems efficiency in order to diminish the amount of waste.

Keywords: Kaizen, bread making, safety, optimization, improvement

INTRODUCTION

Innovation is according to Merriam–Webster Dictionary something new or applied to an existing product as a change referring to a product, idea or field. Several authors (*Tohidi, H., Jabbari, M.M., 2016*), mention innovation as a defining success factor for productivity, ensuring a company profit and competitiveness through the market. OECD Glossary of Statistical Terms defines process innovation as the implementation of a new or significantly improved production or delivery method, including significant changes in the manner of techniques and/ or software. (*OECD, 2005*) Process innovation intends to decrease unit costs necessary for production process or delivery, increasing quality and produce or deliver new or significantly improved products. (*OECD, 2005.1*)

The concept of "lean manufacturing" is considered today a practice in production management, which is based on the idea that material resources should be used only where value is created, that effort, space, warehouses should be as little as possible, and losses of any kind must be eliminated. The premise of the emergence of the concept of lean manufacturing organization was the development of total quality management – Total Quality Management (TQM). It involves an approach to improving the quality of products and services by continuously improving all processes related to their manufacture, quality orientation on customer perceptions and needs, production without defects. The focus of production management is a priority on improving processes, reducing attention to employee criticism (criticism at the organizational level) and the decision–making process based on data. Thus, TQM is an integrated management philosophy and a set of practices that focus on continuous improvement, meeting customer requirements, reducing the repetition of processing or work processes, long–term thinking, increased employee involvement and teamwork, redesigning the process, competitive benchmarking, problem solving in the team, constant measurement of results and closer relationships with suppliers.

The philosophy and lean thinking are based on two practices, namely: elimination of losses from the production process (MUDA), which is the most important, and continuous quality inspection (JIDOKA), the latter practice being an operational process designed to ensure a level "0" of losses or within accepted limits (*Gamage, J., et al., 2010; Rao, P.S., Niraj, M., 2016*). As a result, the objective of continuous reduction of losses (waste of any kind, materials, labour, unnecessary operating times, etc.) leads to a decrease in the time between launching the order from the customer and shipping the products to him, production management being permanently concerned with eliminating "Everything that increases time and cost."

Lean manufacturing (LM) has been proved to be an efficient instrument in manner of providing products or services with excellent attributes to clients by reducing waste, improving productivity, training the staff and improving quality. Lean manufacturing tools have been frequently used in companies that export products worldwide, mainly to developed countries. The key element of LM is mass production and it should focus on improving performance of production processes in order to create high quality products. LM is considered an adequate example of process innovation concerning companies, focusing on continuous improvement as a main groundwork. Senior management is implied in ensuring resources for providing high–quality products and outstanding processes by using different methods or instruments such as lean manufacturing (Kaizen, 5's, reducing the seven crucial waste categories, SMED). Nowadays, manufacturing process is perceived by two approaches: sustainable economic growth and the failing of old management styles related to employees without no multi–task training. (*Landers, R.G., et al., 2020*)

According to the lean philosophy, activities that do not generate added value are identified and are either reduced in duration or eliminated, which leads to reduced

manufacturing costs, improved productivity, quality and, finally, reduced product delivery time to the client. The lean philosophy was created starting from the idea of eliminating any type of losses that may occur in the production system. The concern for reducing and eliminating losses is closely related to the "supreme" desire of manufacturers to generate added value to the finished product, in accordance with the expressed needs of customers. The seven types of losses defined are: overproduction, waiting, transport, unnecessary processing, unnecessary stocks, movements, defects. Following this point of view, to the seven losses was added an eighth loss supported by Toyota's philosophy: stopping the creativity of employees. Lean production uses half of the human effort, half of the production space, half of the investment to make the means of production (tools, devices, verifiers, etc.), half of the scheduled, standardized hours, so that the development of a new product requires half from the time determined in the classical variant.

Food industry is one of the most complex and unique industries comparing to other industries and the application of lean manufacturing was often perceived as an advantage due to a series of advantages such as: extra output, lower costs, better yields, improved systems, better working environment, keeping in contact with consumer needs, eliminating contamination.

LM was perceived as rather difficult to apply in food processing industry. Several authors (*Dora, M.K., 2014*) identified a sequence of factors that are considered important when deciding to apply LM principles: the high perishability of products, complex process flow, diversity of raw and auxiliary materials, oscillating demand.

Bread making, as a branch of food industry with significant importance in the national economy of states is one of the most challenging industry considering the continuous change of raw and auxiliary materials used and applied technologies. The bread making market needs to find a way to overcome the challenge of the economic crises and operational cost increase – raw components, energy and other resources. (*La Sala, P., 2017*) As a consequence, the main questions of the current study are: Can Lean Manufacturing improve the quality of the final products? In what extent the efficiency of the process will be higher? The competitiveness of the business can be enhanced?

MATERIALS AND METHODS

— 5S Methodology

The methodology represents a systematic form of management that involves the usage of multiple instruments from several areas, such as floor type, workplace cleanliness, ergonomics and work area organization. The 5S methodology leads on five pillars, named after Japanese stages: Seiri, Seiton, Seiso, Seiketsu, Shitsuke. The stages are represented and explained in Figure 1.

The steps describe the stages of visual management, each term starting with S and having a corresponding definition in English as related in Figure 1. 5S is an indispensable ingredient of the management of the workplace, of a good administration of the processes and the activities related to it.

Figure 1 – The 5S Concept

Through a good management of the inventory, the materials related to their activity, the employees acquire and practice self–discipline. 5S activities include:

- *seiri – sort*: the right arrangement. It involves sorting unnecessary objects from work. For example, machines, tools, devices, unused defective products, etc. should be removed from work;
- *seiton – set in order*: sort the remaining objects. Each rack or pallet of tools must have a well–defined place so that its location can be easily identified for use;
- *seiso – shine*: cleans, cleans everything that remains. Clean and paint to give you a pleasant appearance;
- *seiketsu – standardize*: personal cleaning. Keep the workplace clean of dirt, dust and oil to provide a pleasant working environment;
- *shitsuke – sustain*: discipline. It means work instructions, safety measures, better discipline and a work culture.

Visual Management is promoted in the workplace so that all employees understand correctly, transparently and can manage their own activity in a safe, clean and organized environment, which accelerates communication and continuous improvement. It facilitates the dissemination of information on the current, actual situation of the production flow (for example, information on the safety of the working environment, operations, stored quantities, quality level and condition of the equipment, etc.), production, thus providing motivation and feeling of pride to continue the activity at maximum intensity (*Steenkamp, L.P., et al., 2017*)

In recent years there has been a revival of visual management in the management of production and operations, as the concept has evolved and its techniques have diversified. Researchers study the implementation of visual management independently of other lean practices (*Bateman, N., et al., 2016*), especially in the context of continuous improvement efforts. Therefore, modern visual management goes beyond the provision of information on the evolution of key processes or performance indicators (KPIs) and also includes strategic information and the

visualization of continuous improvement progress. (*Bateman, N., et al., 2016*)

Recent empirical studies suggest that visual management facilitates the sharing of strategic information between departments within a company and involves the involvement of teams in continuous improvement (*Bateman, N., et al., 2016*), both of which are key factors for the success of initiatives in this field. Overall, the importance of visual management has increased, as it is used more as a control and guidance tool to support continuous improvement initiatives, than as a principle for job design. Given the extended role of visual management in today's production environment, more research is needed on this topic to facilitate its application in the practice of different organizations. (*Tezel, A., et al., 2016*)

— Single Minute Exchange or Die (SMED) Methodology

Changing tools "in one minute" (Single Minute Exchange of Die, SMED) is a fast and efficient method of converting a manufacturing process related to making one product to another (next). In the case of lean manufacturing, the goal of reducing time loss has led to the creation of orderly tool storage devices, which allow their extremely rapid change in order to reconfigure the machines for a new operation related to the technological flow of making another product. The concept states that all steps, the maneuvers to be performed can take less than 10 minutes. Also, the rapid change of tools helps to reduce costs due to time savings, as well as an increase in the flexibility of the production system. (*Godina, R., et al., 2018*)

This method aims to increase the flexibility of manufacturing by reducing the time required to change the manufacturing series, changes that have a long duration, have a complex character and are performed by highly qualified workers.

The analyses performed highlight the fact that the size of a manufacturing series is proportional to the cost of launching into manufacturing, which, in turn, is proportional to the time of changing the equipment for adjustments. To reduce by 50% the time of changing the series, the size of the manufacturing batch must be reduced to 70% compared to the initial economic quantity of the batch, and for a 75% reduction of the change times, the batch to be launched in manufacturing must represent 50% of the optimal batch size.

It follows that in order to reduce the change times of the manufacturing series, the size of the manufacturing batches must be reduced, which at the same time responds to the requirements of increasing the production flexibility.

Following the reduction of the change times of the manufacturing series at the MAZDA Japanese plant, the SMED method was designed and applied.

Following the process of changing the manufacturing series, according to the method, internal operations were identified, which require a stop of the machine, so a stop of production and external operations that can be performed when the machine is in operation and does not require stops. (*Ulutas, B., 2011*)

The application of the SMED method has as starting point the analysis of the existing situation, with the question – "What?", following the choice of the sector that requires the most urgent improvement and to apply the reduction methodology to answer the question – "How?", going through the following steps:

- *Stage 0*: Observing each operation in order to determine as accurately as possible the time required to perform each operation;
- *Stage I*: Separation of internal operations from the external ones;
- *Stage II*: Transforming as much as possible the internal operations into external operations;
- *Stage III*: Rationalization of the settings for the transition to the new manufacturing series.

By applying the method, the aim is to reduce the internal operations to the minimum necessary and to reduce the stopping times by passing some internal operations in external operations that can be performed without the need to stop the production process. (*Costa, E., et al., 2013*)

RESEARCH METHODOLOGY

The research was carried out in a bread making organization located in Romania and trading on the Romanian market. The name of the company is not going to be published for data protection reasons. The data collected from the company was analysed in order to complete the qualitative research of the current study. The company was aimed to diminish the number of nonconformities and increase working satisfaction towards the employees, reaching to the need for continuous improvement.

The bread making company focusing on the current study is one of the major companies in the field from the Romanian industry with 12 factories and over 150 stores. The organization includes milling units, production units and selling units, counting about 6000 employees in 2019. The company produces fresh bread and bread products, frozen products and milling products – flour, bran, and hominy. In the last years, the company managed to trade the products across the border reaching to different countries. The study was focused on fresh bread production, the working shift being divided in three shifts and three technological flows – white whole–wheat bread, intermediate bread, and whole wheat bread. The case study was developed on the main technological flow – white whole–wheat bread production applying 5S and SMED methodology. Considering the fact that the internationalization of the company has become more intense, it was considered convenient to apply lean manufacturing principles in order to improve process efficiency.

RESULTS

— Application of 5S and SMED method on the process

The study was focused on one of the technological flows – white wheat bread production. The technological flow

produces white wheat bread – 300g, 500g and 1000g and white wheat buns – 50g.

In order to apply lean management instruments, the staff was taught on the principles and regulations that were going to be applied, lean management instruments were explained and the aim of the applied methods. Both applied methods were explained and motivated, so the staff could better understand and assume the working procedures in order to achieve better results and ensure the success.

— 5S methodology

The methodology was supposed to be applied on a series of working areas in the factory – raw and auxiliary materials reception, raw and auxiliary materials dosing, raw and auxiliary materials preparation, dough dividing, baking and cooling. Firstly, all the steps were analysed concerning the organization of work, equipment, staff distribution, staff movement and materials flow.

The main matters identified were: disorganized equipment, storage of the raw and auxiliary materials, distance between storage and equipment, excessive quantity of raw materials existing in the technological flow area (flour bags deposited on the floor near the equipment). The existence of these matters was affecting productivity and work efficiency. In some cases, the matters could affect workers safety and health: the presence of raw and auxiliary materials on the floor caused a slippery surface and endangered the safety of workers, the flour bags disturbed workers movement. Also, the cleanliness of the surfaces encouraged the development of several microorganisms – mould and bacteria.

The analysis of the current status of the production was performed according to the issues required by the 5S methodology and was adjusted on each work area.

Table 1. 5S check list applied

Category	Check item	Evaluation Criteria
1S: Sort "Eliminate the items that are not useful from the production area"	Materials	Excessive raw material bags, empty bags, containers resulted from the emptying of raw and auxiliary materials?
	Equipment	Equipment that is not used in the area, defective equipment present?
	Tools	Unnecessary tables, bowls, knives, scissors, tools?
	Supplies	Excess cap, gloves stored in the area?
	Documents	Procedures, regulations, organizing instructions stored on the workstations?
2S: Set in order "Reorganizing the items required for production so as to be easy to access and to use"	Jars	Raw and auxiliary materials jars are accessible and labelled? Jars are filled at the beginning of the production flow?
	Placement	Jars are easy to use? Containers are easy to identify? Containers are located near the equipment? Supplies are accessible to workers? Disinfecting areas are situated near the production entries?
	Floors	Marked and properly cleaned?
	Tools	Easy located and accessible? Cleaned and set in order?
	Instructions, regulations, standards	Accessible for workers? Easy to read and observe? Easy to manipulate?
3S: Shine "Cleaning the production areas and implying the workers in the cleaning process of the working area"	Equipment	Clean and located correspondingly? Cleaning schedule is performed regularly? Cleaning agents are used properly?
	Supplies	Supplies are kept in separate areas? Supplies are kept in disinfected containers? Supplies are stored in separate areas?
	Tools	Tools are cleaned regularly? Tools are cleaned on a regular basis or schedule? Cleaning register is kept?
	Work areas	Floors are cleaned regularly? Disinfectant bottles are filled regularly? Cleaning is performed on a regular basis?
4S: Standardize "The workers develop activity in the same way and according to the same regulations"	Tools	Tools are suitable according to the regulations? The material of the tools is standardized?
	Materials	Raw and auxiliary materials are stored according to the standard regulations? The handling of raw and auxiliary materials is standardized?
	Equipment	Equipment is maintained and operated corresponding to the standard regulations? Equipment is configured according to the standard procedures?
	Standards	Visibility of the standard procedures is ensured? Standards are continuously updated according to the period? Workers are trained according to the standard procedures?
5S: Sustain "The workers take control of all the actions that happen in the organization"	Work area	Disinfected, clean, organized and tidy? The procedures suppose organization of the workplace? All the tools and equipment are on the right place?
	Documents, procedures	Are procedures updated and revised regularly? Documents and procedures are current? Check the application of procedures?
	Workers	All the workers are 5S trained? New workers are 5S trained?
	Equipment	Equipment is periodically technically checked? Equipment is set on the right place?

— SMED methodology

Analysing the sequentially of the tools in the manufacturing process, one of the tools was identified as important for innovation – baking area. It was observed that the area had, during a month, about 30 changeovers, the times between changes being estimated at about 15–20 minutes. This aspect was noticed for improving efficiency and productivity. Among all the equipment, one was identified as significant: tunnel oven. SMED methodology was implemented in order to reorganise the changeover process between charges.

The first step to implement SMED was a critical analysis of the actual conditions and manufacturing system. The importance of this study was relevant due to the fact that a better understood of the switchover actions and potential disfunctionalities can help to improve the process. The research was conducted by continuous monitoring, communication with the staff involved in the process and finding out process details. The data were collected from

head manager and process engineer and concluded the following aspects: the period to develop actions was too long, the time to charge and discharge the trays with the products was prolonged, the staff had to change the equipment and gloves after each stage and the position of the trays was not adequate – too far from the oven.

The main issue observed was that the workers had different working procedures for the same operation – fact that implied long times for processing and transition. Among the 15 workers in this area, 7 had their own strategies for developing the same task. It was also observed that the staff proceeded to introducing the trays with the products in the oven just few minutes after the oven was ready. Several disfunctionalities identified in this area were the following:

- lack of staff training;
- lack of procedures;
- the indicators for placing the trays and other instruments were missing;
- absence of standards and documents that regulate the working directions;
- lack of training in equipment functioning.

Table 2. Number of assignments and duration of each action before applying SMED methodology

Actions	Baking	
	Duty	Duration
Shutdown	5	00:15:22
Configuration	24	01:10:14
Startup	7	00:32:14
Total	36	01:57:50

The duties were classified as internal or external and organized according to the SMED methodology regulations. The convert stage focused on converting the configuration stage into external (introducing water into the container for steaming system, adjusting conveyor belt speed, setting baking temperature). Performing tasks before the first charge and filling the container while adjusting conveyor belt speed and adjusting temperature in the same time by three operators, not just by one single person were a series of modifications applied. In table 3, can be observed how the number of assignments and duration of each action was diminished.

Table 3. Number of assignments and duration of each action after applying SMED methodology

Actions	Baking	
	Duty	Duration
External	5	00:10:34
Shutdown	0	00:00:00
Configuration	23	01:00:04
Startup	5	00:20:14
Total	28	01:20:18

Diminishing the configuration times and charge and discharge periods, provided several increases in profit with minimum financial investment. In addition, it was established a series of facts that were really encouraging: regulation of several procedures, work area organization, visual management concepts application, organization of storage and working areas and improvement of the manufacturing system.

Considering the reminded and analysed aspects, the lean manufacturing concepts were really effective for improvement and can be considered as a first step in the continuous improvement process.

CONCLUSIONS

This paper presented an application of lean manufacturing procedures in a breadmaking factory. The implementation was considered effective, leading to several gains concerning the organisational procedures and financial gain. This procedure can be applied in order to improve production flexibility and continuous improvement methodologies. Considering this aspects, lean manufacturing concept can be successfully applied in several other areas, bringing benefits for both manufacturers and involved staff.

Lean methodology, which has evolved over time from a set of principles of organizing production processes to a true organizational culture, and which aims to create value for the customer, while reducing costs, shortening process cycles and improving quality can be considered a reference for manufacturing companies involved in production.

Furthermore, the paper highlights that the workers involvement in the production represents the definitive aspect for successfully implement lean manufacturing methodology in a large category of areas.

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[1.]Lissette CONCEPCIÓN MAURE, [1.]Norge Isaias COELLO MACHADO, [1.]René ABREU LEDÓN, [2.]Elke GLISTAU

LEAN MANUFACTURING, INDUSTRY 4.0 AND SUSTAINABILITY: ESTABLISHING A RESEARCH AGENDA

[1.]Central University "Marta Abreu" from Las Villas, CUBA
[2.]Institute of Materials Flow and Logistics, Otto von Guericke University, GERMANY

Abstract: The current competitive environment of manufacturing is characterized by, among other things, increasing global competition, shorter product life cycles and increasing individualization of products. This puts pressure on the flexibility of manufacturing companies and on the efficiency of their resources to meet customer demand and stay competitive. To meet these challenges, companies are forced to continually innovate and improve their operations management strategies and processes. Lean manufacturing has been the most prominent methodology for improving the operational performance in manufacturing companies for several decades. Similarly, industry 4.0 is one of the most promising approaches to meet future challenges in the production environment. Different approaches are considered in the literature to analyze the link between these two domains. However, few studies investigate how these philosophies should be integrated to offer a streamlined and high quality transformation process, and their respective influence on the three main pillars of sustainability: economic, environmental, and social. The purpose of this paper is to present a review and analysis of the literature on the relationship between these three management systems. A conceptual framework for an integrative approach to LM, I4.0 and sustainability is also developed, pointing out the achievements and the gaps found in the literature.

Keywords: lean manufacturing, industry 4.0, sustainability, review, conceptual model

INTRODUCTION

Sustainability is the ability to meet current needs without compromising the ability of future generations to meet theirs, ensuring the balance between economic growth, environmental care and social well-being. This concept became widely used three decades ago after the consequences of human activities to the Earth's ecosystems had been realized. These were recorded from the first industrial revolution inevitably correlating those issues with industrial development [18]. Despite the multiple studies carried out, it is still difficult to choose the criteria and strategies that allow characterizing, evaluating and achieving an adequate degree of sustainability in the organization.

Based on current research, Lean Manufacturing (LM) and Industry 4.0 (I4.0) strategies are promising in this regard. In the literature, there are works on separate effects of LM and I4.0 on Sustainability, as well as high compatibility between both, where one strategy comprehends the use of another. However, only a few articles consider the integrated eff and mostly lack empirical validation [13].

LM has been defined as an integrated set of socio-technical practices designed to eliminate waste along the whole of the value chain within and across companies by focusing on the activities that create value for the customer. [12]. Since its introduction, the lean approach has increasingly expanded in the field of operations management until it has now become a fully holistic business strategy [5].Numerous tools, techniques and practices have been developed over time for this approach to be implemented, and many others that already existed have easily slotted into Lean's broader focus. its features are not restricted to the elimination of waste but cover the optimization of many manufacturing processes from product development to distribution.

According to a survey released in 2007, almost 70% of American manufacturing plants have implemented some form of lean manufacturing project [21]. While, a survey from Germany reports that over 90% of the surveyed manufacturing companies claim to have initiated a lean manufacturing initiative [9].

However, given the increasing complexity of operations, many companies have found that LM by itself is not sufficient to address their operational challenges.

Recently, a set of advanced digital technologies known as I4.0 has emerged to offer new approaches for dealing with complexity and improving productivity. By deploying the right combination of technologies, manufacturers can boost speed, efficiency, and coordination and even facilitate self-managing factory operations.

The I4.0 is the first industrial revolution to be announced in advance. Although a great opportunity to shape and optimize the solutions before they are fully released, the lack of empirical data makes the research highly theoretical or aimed at implementing solutions to very specific problems. All in all, I4.0 is seen as the future of manufacturing and is presented as a concept that manufacturers need to embrace to stay competitive.

The purpose of this study is, therefore, to explore the relationship of Lean and I4.0 with respect to sustainability from the review of the existing literature, analyze current proposals, identify gaps and define future lines of research.

Following this introduction, the study was divided into three parts. The following section "Materials and methods" exposes the main concepts about LM, I4.0 and sustainability, it also describes the methodological approach followed to

develop an adequate review of the literature. The third section is dedicated to outlining the main influences of LM and I4.0 on the three dimensions of sustainability. A conceptual framework for an integrative approach to LM, I4.0 and sustainability is also developed, pointing out the achievements and the gaps found in the literature. Finally, the conclusions focus on challenges that future research should address.

MATERIALS AND METHODS

This section aims to present a summary of the concepts which guided the selection and analysis of the papers in order to summarize a construct about the links between LM, I4.0 and sustainability.

— Lean Manufacturing

LM has been defined in many different ways. One reason for the lack of a coherent definition might be that the concept is still evolving [11]. However, the main goal of a lean system is to produce products or services of higher quality at the lowest cost and in the least time by eliminating wastes. In the lean context, waste (Muda) is any activity that consumes resources and time but does not create value.

A lean concept, in general, considers seven main losses: overproduction, defects, waiting, over-processing, unnecessary or ineffective inventory, motion or non-value-generating activities, and transportation, where each of these has sustainability impact. In theory, the likelihood of a philosophy like Lean that stands for the elimination of waste to support sustainability is high. Several works arrive at the same conclusion [15, 26]. However, eliminating what Lean perceives as waste does not always necessarily improve sustainability performance [7].

Apart from a holistic management focus based on a number of objectives and principles, lean also encompasses a set of practices, tools, techniques and methodologies. LM includes many tools, e.g., Muda, Jidoka, Just-in-Time (JIT), Value Stream Mapping (VSM), Kanban, Poka Yoke, Kaizen, 5S system, Root-case analysis, Zero defects. To understand how this affects sustainability, each principle and its impact should be considered.

LM may be viewed as a configuration of practices/tools because the relationships among the elements of LM are neither explicit nor precise in terms of linearity or causality. A configuration approach helps to explain how a lean system is designed from the interaction of its constituent elements taken as a whole, as opposed to designing the system one element at a time. From a theoretical standpoint, lean management is seen as a tightly coupled system where the constituent elements hold together in mutual dependence. It is the self-reinforcing effects of this kind of mutual dependence that contribute to the superior performance associated with lean management on the one hand and make it rare, valuable and difficult to imitate by competitors on the other hand [25].

— Industry 4.0

Several elements within the I4.0 concept have been handled: integration of complex machinery and devices, with software networks and sensors, used to predict, control, improve the business and its impact on society [19]; new level of organization and management of the value chain throughout the product life cycle [22]; holistic system of IT, people, machines and tools, which allows the flow of goods, services and data in a controlled way, through the value chain, with operations of a high degree of autonomy and capacity to transmit useful information in the decision making [23].

I4.0 concept is associated with the technical perspective of a Cyber Physical System (CPS) integrated into manufacturing operations and with Internet of Things (IoT) technologies into the industrial processes, which can be represented by smart factories, smart products, and extended value networks – vertical, horizontal and end-to-end integration.

This phenomenon will be the most powerful driver of innovation over the next few decades triggering the next wave of innovation [15].

Different authors state that the I4.0 can support value creation in all sustainability dimensions and, in this matter, they identify opportunities for industry development considering: development of business models driven by smart data, offering new product-services; closed-loop product life cycles and industry symbiosis creating value networks; equipment using CPS for retrofifitting SMEs (Small- and Medium-sized Enterprises) digitization; trainings and competence development supported by ICT technologies; motivation and creativity fomented by programs supported by CPS; sustainable-oriented decentralized organization focused on resource efficiency; sustainable process design using new technologies promoting closed-loop life cycles and cradle-to-cradle approaches [4].

To support effects of a solution on the sustainability dimensions, each sustainability dimension represents a specific system evolving around a digital value-creation solution, so one adopted solution can create direct impacts on one dimension system, but also have indirect effects on the other dimension systems of sustainability. The interactions between sustainability systems can occur in three different types: causal relations (effects between a solution and its direct and indirect impacts); magnitude and scale driver (direct and indirect impact is determined by the magnitude and scale of a solution's dissemination); and latency and timely duration dependencies (between effects and impacts) [10].

— Sustainable manufacturing

Sustainable Manufacturing can be defined as the integration of processes and systems capable to produce high quality products and services using less unsustainable resources and more sustainable resources, being safer for employees, customers and communities surrounding, and being able to

mitigate environmental and social impacts throughout its whole life cycle [3, 10].

This author defines the sustainable manufacturing scope in four areas with its respective objects and applied disciplines:

- Manufacturing technologies (how things are manufactured) with focus on process and equipment (machine-tool, facility);
- Product life cycles (what is to be produced) with focus on product and services' design;
- Value creation networks (organizational context) with focus on organizations of companies and manufacturing networks;
- Global manufacturing impacts (transition mechanisms towards sustainable manufacturing) with focus on studies about manufacturing impacts on the world, including society, environment, and economy.

Different aspects can contribute to a positive sustainable manufacturing strategy implementation, among others, the development of sustainability indicators, policies and procedures, company's cultures and internal conditions for sustainability, sustainable design strategies, and stakeholders' engagement for sustainability and technologies [2].

There are no criteria/KPI or universal models that can characterize and evaluate the degree of sustainability of an organization. Sustainability is therefore measured through indirect quantitative parameters using the triple bottom line (TBL) approach consisting of economic, environmental, and social pillars.

SYSTEMATIC LITERATURE REVIEW

The primary approach used in the study is a systematic literature review. This method has numerous advantages compared with traditional unstructured reviews. It adopts a replicable, scientific and transparent process that allows: minimization of bias and errors; improvement in the quality of the review process and outcomes; confirmation of their validity through the replication of clear steps during the review process; and synthesizing and organizing the literature accumulated in a specific field, often providing academics and practitioners with frameworks of the existing knowledge.

A structured process was adopted according to the sequence o outlined below:

Scopus was used as the index from which to identify documents for this review. Scopus offers a wide coverage of disciplines that were deemed relevant to the interaction LM, I4.0 and sustainability as well as access to bibliographic data used by bibliometric software.

The 'source' of documents was left open-ended during the search as opposed to predefining a specific set of journals. In terms of 'types of documents', the review included articles, conferences, and book chapters. The search is framed in the period of time between the years 2010-2022.

This approach assumed that authors writing on this topic 'self-organized' the literature through the use of terms used to describe their research in the title, abstract, and keywords of their papers.

The following string of keywords is used to generate the initial database of documents in Scopus. Several existing terminologies to refer to both LM and I4.0 are considered to perform the search. As well as the terminology referring to sustainability, sustainable development and the three axes of the TBL.

TITLE-ABS-KEY ('industry 4.0' OR 'cyber physical production system' OR 'digitalization' OR 'smart manufacturing' OR 'smart production' OR 'smart factory') AND TITLE-ABS-KEY ('lean' OR 'lean manufacturing' OR 'lean management' OR 'lean production') AND TITLE-ABS-KEY ('sustainability' OR 'sustainability development' OR 'operational sustainability' OR 'environmental sustainability' OR 'social sustainability')

This search returned 88 documents. Scopus filters were used to filter documents based on broad categories (language: English, publication stage: final), reducing the database to 72 articles, 18 subject area, 46 publication sources, 231 authors, 2 345 references.

The convergence of LM, I4.0 and sustainability is a topic which has evolved in recent years, and papers' distribution indicates an evolutionary trend compatible with a new research field (figure 1).

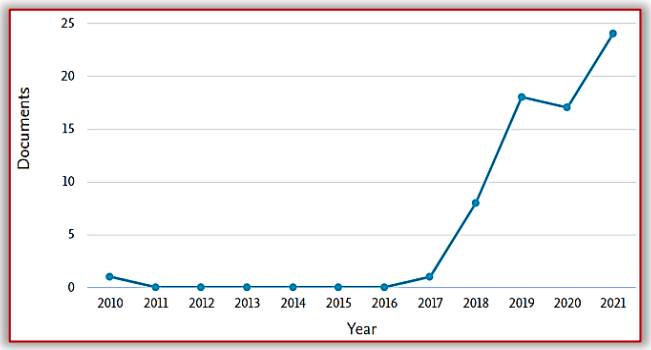

Figure 1. Distribution of articles by year

As identified several authors [6,8], the scope and disciplines concerned with sustainable manufacturing are multidisciplinary, and the same trend is being applied in the context of the I4.0. Figure 2 shows the documents organized by subject area. The most representative areas are those referred to: engineering (25.4%), business, management and accounting (16.2%) and computer science (14.5%).

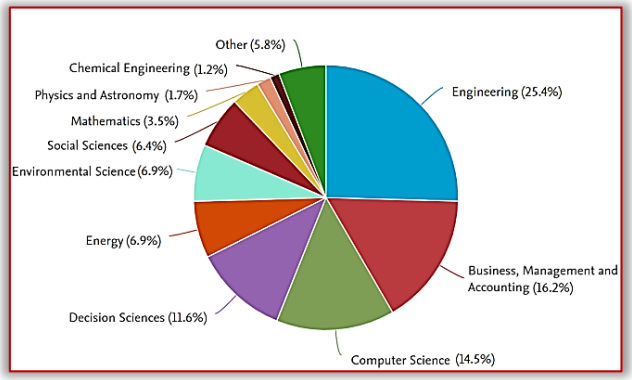

Figure 2. Distribution by subject area

The list of journals and conferences more representative in the sample is available on Figure 3, allowing to identify allowing to identify the most relevant journals in the last 5 years.

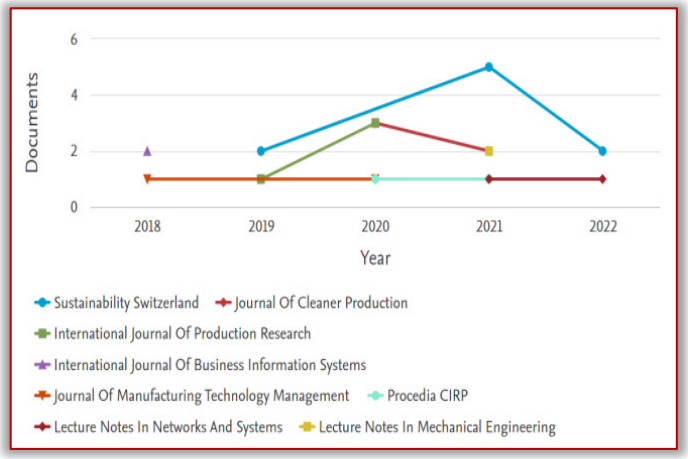

Figure 3. Documents per years by source

Analysis of keywords co-occurrence was the bibliometric method used to map the research field. The process of creating keywords networks and clustering keywords was supported with the use of the VOS viewer application, developed by the Centre for Science and Technology Studies of the University of Leiden, the Netherlands.

The papers comprising the research sample provide 189 keywords. The most often cited expressions are: industry 4.0 (54), sustainability (48) and manufacturing (26). The minimum number of occurrence of keyword is 2, in consequence, the number of high-frequency keywords in the co-occurrence network is 172, for building a network with 6 cluster, 1442 links and 1481 total link strength. In the map the size of nodes manifests the frequency of keyword's occurrence, while lines show relationships among keywords (see Figure 4).

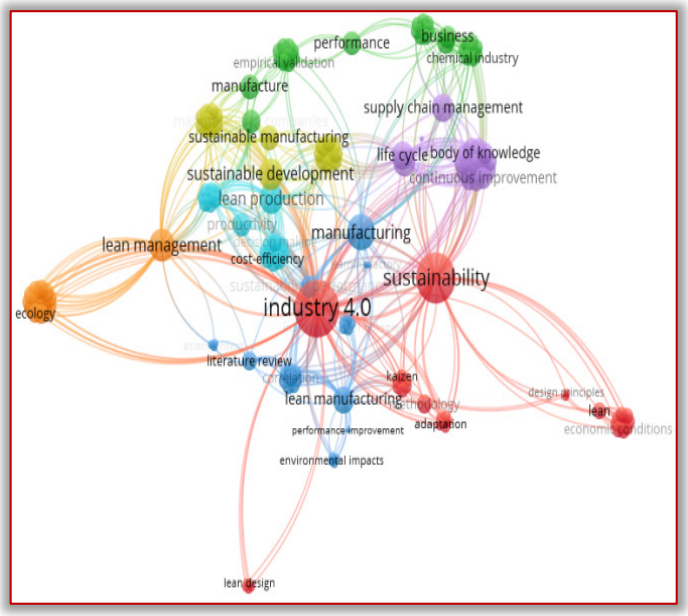

Figure 4. Keywords' Network visualization

- red cluster: I4.0 enablers and some LM tools increase sustainability
- orange: sustainable smart production. lean production practices and waste elimination at all stages of the life cycle, ecological impact
- green cluster: management system and impact on business performance.
- purple cluster: sustainable design and life cycle assessment. supply chain management
- yellow cluster: sustainable value creation for smart factories
- blue cluster: lean manufacturing practices and impact on the different edges of sustainability.

An analysis of the visualization overlay network shows that this is a recent research area, where the most current themes focus on designing new business models and measuring the impact on operational performance, social and environmental impact (Figure 5). It is not until 2020 that a greater interaction between LM, I4.0 and business sustainability can be seen in the reviewed literature.

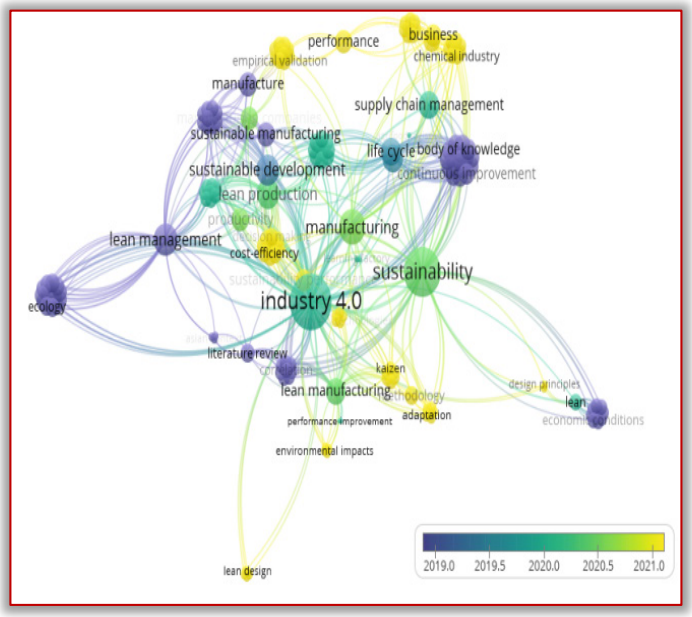

Figure 5: Keywords' Network overlay visualization

RESULTS AND ANALYSIS

Based on the reviewed literature on LM and I4.0 interconnection, the perspectives could be grouped into three categories: LM as a basis to I4.0, I4.0 enhances LM and positive correlation between the two. The third perspective stating that current demand for digitalization needs an extension of the lean production system to integrate new technologies on the shop floor. The combination of lean and I4.0 is argued to not only bring short-term operational excellence but also to contribute to long-term sustainability.

— Lean Manufacturing and Sustainability

This sections discusses the relations between LM and the three dimension of sustainability. Companies that have adopted LM to improve their results also want to be seen as socially responsible. Sustainability is considered the new LM frontier [3]. Productivity and cost-saving are necessary for

the economic survival of organizations. However, these tasks should be achieved in a sustainable way, by mitigating negative environmental and social impacts and contributing to a sustainable society [20].

In Table 1, a resume about some main contributions regarding the relation or influence of LM in the three dimensions of sustainability are presented.

Table 1. Influence of Lean Manufacturing in the dimension of sustainability

Dimension	Influence
Economic	Increase profits
	Increase turnover
	Increase market share of the products
	Decrease operational costs and production cost
	Increase process performance
Environmental	Decrease industrial waste
	Increase the practice of circular economy
	Increase the collaboration with partners that follow good environmental practices
Social	Increase the participation of its employees in decision-making and liability
	Increase the quality of work conditions
	Increase in workplace safety

The author [1] indicates that when considered as a whole, lean positively impacts business performance on an aggregate level, as well as market performance individually. However, these effects are highly variable. This high variability therefore offers great opportunities for further research into the potential moderating variables that may affect these relationships.

The authors [16] establish a link between lean and green showing that adopters of lean manufacturing principles are more likely to also adopt ISO 14000 environmental standards. Results show, as expected, that the main impact of lean is related to an increase in the productivity and efficiency of manufacturing processes. It also identifies a very positive relationship between lean implementation and employee satisfaction and it positive impact on the company financial strength. These two aspects together indicate that implementation of lean methodologies can lead to an increased sustainability of the company.

— Industry 4.0 and Sustainability

I4.0 has changed the way businesses and production are conducted in their entirety, in terms of procedures, methods, and practicability. The cost of I4.0 infrastructure seems to be reasonable when budgeted environmentally, but it is still difficult to predict its direct impact on sustainability.

The Table 2 show main recent contributions that have emerged for researchers on I4.0 and sustainability, underlying main dimensions considered are summarized.

According to the reference [6], environmental sustainability is positively impacted by I4.0 through comprehensive digitization that provides more accurate, high-quality management and real-time event management for the external environment.

Table 2. Influence of Industry 4.0 in the dimension of sustainability

Dimension	Influence
Economic	Increase: profits, value creation, efficiency, flexibility
	Increase turnover, and create new business models
	Increase in market share
	Decrease operational and production costs
	Improve processes performance, increase renewable resources, and improve circular economy
	High revenue through vertical and horizontal integration
Environmental	Decrease industrial waste
	Decrease energy intake of non-renewal energy sources
	Increase production of renewal energy
	Practice of circular economy
	Increase in development of new green technologies
	Increase collaboration with partners that follow good environmental practices
Social	Corporate social responsibility is undertaken by companies towards consumers
	Customization and digitization
	Improve conditions of the surrounding society
	Decrease working accidents
	Increase participation of employees in decision-making and liability

It should be noted that sustainability is a broad concept; therefore, flows chosen to address environmental sustainability have already been used elsewhere. When an event is implemented, calculations of flow patterns will become simpler. Nonetheless, the positive effect of activities on the flows is highly dependent on the production quantity. When production increases, flows will also increase and there will be a transformation of negative impacts into positive trends by adopting an e-commerce environmental sustainability dimension.

Therefore, a gap still exists on how to integrate the efficient use of scarce resources, raw materials, information, responsible consumption, and energy with sustainable development goals in long-term solutions. To reduce pollution in the environment and achieve sustainability, the 4Rs—reduce, reuse, recycle, and replace—can be used. Hence, efficiency and eco-innovation will be realized in I4.0 and the sustainability.

The first rule of any technology used in a business is that automation applied to an efficient operation will magnify the efficiency. The second is that automation applied to an inefficient operation will magnify the inefficiency'. – Bill Gates (cited in [17]).

This quote illustrates why lean thinking is still important in an increasingly automated and digitalized world. It highlights the inevitable fact that an inefficient process that is automated is still inefficient and is basically automating some type of waste. The cost of automating an inefficient process also tends to be higher [14, 24].

However, several of these studies only discuss and hypothesize on a conceptual level, while some of the empirical studies collect their data from secondary sources. To motivate an I4.0 and lean manufacturing integration, it is necessary to further investigate the potential performance implications through empirical studies. Although the current sample of studies gives some indications on the potential performance impacts, the studies are clearly insufficient in both width and depth. Central research issues in the future will be to measure what a successful I4.0 and lean manufacturing integration entails, as well as comparing the sustainability impacts with those of a 'pure' I4.0 or lean manufacturing system.

Some topics are more developed and are moving towards a normative approach, such as energy efficiency, life cycle management, use and analysis of big data, and systems integration models; while others present opportunities to be more explored, such as human factors, sustainable products and service development, and global manufacturing impacts of Industry 4.0.

— Conceptual model

The main point of interest for this article is to analyze the link between I4.0 and LM, as well as examine its implications on sustainability and the external factors influencing these relationships. Therefore, the last step is to develop a conceptual model that explains the main constructs and the relationships between them.

The proposed model (Figure 6) illustrates the different theoretical lenses regarding these relationships and establishes a structure for summarizing the findings from the literature presented in the previous section.

The conceptual model, in its graphic presentation, considers the environment as a moderating entity in the potential to integrate LM and I4.0, as well as the impact resulting from such integration on sustainability. The success of the execution of any management practice is closely related to the socio-economic context where it is developed (country, business sector, supply chain) that can influence to a greater or lesser degree, in a differentiated way, on each company analyzed.

The central segment of the model shows one of the currently unsolved problems in the literature, how to apply LM and I4.0 in an integrated way. This integration should allow technology enablers to further support and develop LM practices and in turn these exert facilitating effects on the implementation of I4.0. This integration starts from instituting in the organization the pillars of both work philosophies, generating new business models on their bases.

As the central core of the conceptual model, five strategic points are represented to analyze to evaluate, implement and maintain a transformation project: strategy and business model, processes, organization and human resources, infrastructures, products and services. The two influencing circles on the central core represent lean practices (left) and I4.0 technology enablers (right). Both have been represented in an interrelated way because the implementation of an LM practice or a technological enabler (I4.0) is not simply the sum of the results of each of them. Rather, they complement and work synergistically to create a streamlined, high-quality system that increases business profits. This helps explain how a lean system is designed from the interaction of its constituent elements taken as a whole, rather than designing the system one element at a time. The self-reinforcing effects of this type of mutual dependence are those that contribute to a higher associated sustainability.

At the center of the model and inscribed in the central nucleus, the dynamo of future research, composed in this case by the permanent interrelation between lean production models and IT. Its internal logic of execution, this interaction must occur in an environment of continuous improvement, supported by the four stages of the so-called Deming cycle (Plan-Do-Check-Act).

The model also represents an existing GAP in the preceding studies: how to measure the impact of the changes imposed on the production system by the integration of LM and I4.0 on operational performance and on the different dimensions of sustainability (economic, social and environmental)?

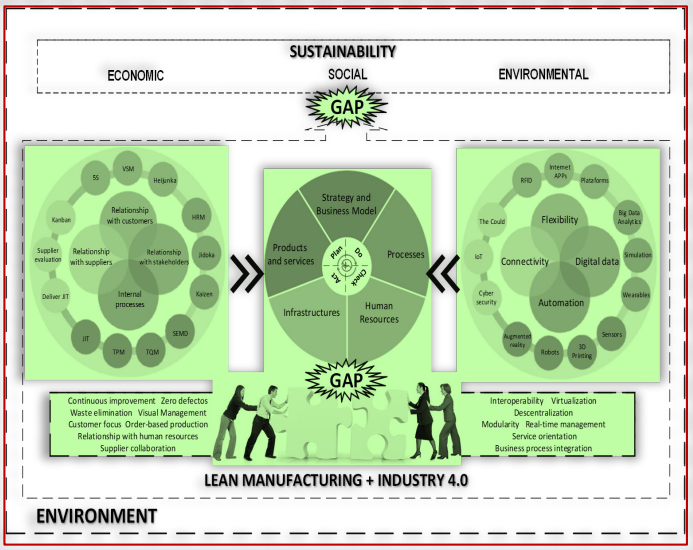

Figure 6. Conceptual model illustrating the relationships between I4.0, LM and sustainability

CONCLUSIONS

In conclusion, after reviewing all these studies, the challenges and opportunities associated with the implementation of I4.0 are still uncertain, and the technologies associated with this industry in terms of sustainability have not been adequately explored because these are still new technologies.

The literature findings are classified into four research streams: (1) I4.0 supports LM, (2) LM supports I4.0, (3) implications of an I4.0 and LM integration in the sustainability, and (4) the effect of environmental factors on an I4.0 and LM integration. It is clear from the findings that

this area is still immature, with seemingly no common platform of knowledge to build the research on.

The conceptual model, in its graphic presentation, considers the environment as a moderating entity in the potential to integrate LM and I4.0, as well as the impact resulting from such integration on sustainability. This proposal illustrates the different theoretical lenses regarding these relationships and establishes a structure for summarizing the findings from the literature.

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[1.] K. K. IKPAMBESE, [2]A. A. ONOGU, [3.] H. C. OLISAKWE

EFFECTS OF BIO ADDITIVES ON TRIBOLOGICAL CHARACTERISTICS OF BIO LUBRICANTS FORMULATED FROM SELECTED BIO OILS

[1.]Department of Mechanical Engineering, University of Agriculture, P.M.B. 2373, Makurdi, NIGERIA
[2.]Works and Maintenance Department, Kogi State University Ayingba, Kogi State, NIGERIA
[3.]Department of Mechanical Engineering, Nnamdi Azikiwe University Awka, NIGERIA

Abstract: In this study, the effect of bio additives on the tribological characteristics of bio lubricants formulated from some selected bio oils was carried out. The Bio additives were obtained from Moringa tree bark, Jatropha stem, Yellow oleander latex, Cocoyam stem and African elemi tree bark using ASTM D5369-93. The characterization of the bio additives was also done using using atomic absorption spectroscopy to determine their active elements. The bio lubricants were formulated by mixing each bio based oil with respective bio additives differently in a ratio of 70 % bio base oil with 30 % bio additives. ASTM standards were used to carry out test on the formulated bio lubricants to determine friction and wear performance. The result of characterization of bio additives revealed the presence of active elements such as Iron (Fe), Nickel (Ni), Copper (Cu), Lead (Pb), Magnesium (Mg), Zinc (Zn) and Manganese (Mn) which improved the properties of bio based oils used as lubricants. Coefficient of friction varied from 0.0815 (bio lubricant from Yellow oleander seed oil) to 0.0895 (bio lubricant from Palm kernel oil). The ANOVA confirmed that there was significance difference in the Coefficient of friction with addition of additives as $F = 57.81651 > Fcrit = 2.866081$. It was observed that the wear increased as the pressure applied was increase for all the formulated bio lubricants. The ANOVA at 5 % significant level clearly showed that the bio additives had significant effect on the formulated bio lubricants in terms of wear depth. This research provides information to lubricants producers for replacement of synthetic and mineral based additives with natural plant additives for lubricants production.
Keywords: Bio-additives; bio-lubricants, Coefficient of friction, Wear depth, Bio oils

INTRODUCTION

Due to increased stringent environmental regulations there are efforts by researchers to develop lubricants which are fully or partially biodegradable and do not have toxic effects on the environment. One of these ways is by utilization of bio additives obtained from natural source of plants and animals [1]. Bio additives are bio-based concentrates that can be added to any lubricating oil to improve lubrication performance. Additives in lubricating oils play an important role in the reduction of friction and wear between two mating surfaces [2]. Without additive, even the best base oils are deficient in some features, as performance of a lubricant depends collectively on the base oil, additives and formulation [3]. Mang and Dresel [4] also affirmed that base oils alone are sometimes unable to meet the lubricant requirement of a component so additives are utilized to improve lubrication by modifying their properties, and performance on the metal surfaces.

According to [3] intensive review of previous works show that vegetable oils and natural plants have potential to be used as lubricants and additives to replace conventional lubricants and additives. At present, lubricants derived from natural sources exhibit a promising potential as a new class of eco-friendly lubricants [5, 6]. Balamurugan *et al.* [7] also affirmed that properties of vegetable oils such as high viscosity index, low volatility, higher shear stability, etc make them more suitable for lubrication over mineral oils. However, their applicability in lubrication is partly limited, as they tend to show low oxidative stability and higher melting points. Shahabuddin *et al.* [6] found that chemical modifications through blending with additives can solve these problems.

Recent studies have focused on the development of fully environmentally friendly lubricants by using bio additives in an attempt to provide suitable alternatives to petroleum based lubricants. Shahabuddin *et al.* [6] studied the comparative tribological evaluation of bio-lubricants formulated from jathropha oil. The bio-lubricants were formulated using 10-50 % by volume of Jatropha oil (JO) blended with SAE 40 as the base lubricant. The experimental results showed that the lubrication regime that occurred during the test was boundary lubrication while the main wear mechanisms were abrasive and adhesive wear. During Cygnus wear testing, the lowest wear was found with the addition of 10 % JO, and above 20 % JO the wear rate was increased considerably. The authors concluded that the addition of Jatropha oil in the base lubricant acted as a very good lubricant additive which reduced the friction and wear scar diameter at a maximum of 34 % and 29 % respectively during the tribo-test. Hence, the application of 10 % bio-lubricant in the automotive engine will enhance the mechanical efficiency and contribute in reducing the dependency on petroleum oil as well. Biodegradable additives of palm oil methyl ester (POME) and castor oil (CO) in soya bean oil (SO) based lubricant for diesel engines was studied by Balamurugan *et al.* [7]. These bio-additives were added to soya bean methyl ester to improve wear resistance and oxidation stability. Various soya bean oil formulations were used as lubricants in diesel engines and the sump oil temperature measured compared favorably with SAE 40. The result revealed that the physico-chemical properties of

the soya bean oils were similar to those of commercial mineral oil. The engine performance and lube oil temperature were not significantly different for soya bean oil as compared with the manufacturer's recommended oil. Hence the blends of soya bean with POME and CO can be used as a crankcase oils.

The increasing environmental issues regarding biodegradability, renewability, toxicity and health and safety risks have been gaining attention towards the development of bio-based lubricants. Some researchers tend to investigate the potential use of vegetable oils [8] and leave the shortcomings of additive formulations, while others are more interested in chemical modifications of these vegetable oils in order to improve their properties [9]. The lube oil properties include both bulk and surface properties, but it is believed that no single molecule can meet all desired properties. Thus, further formulations using additives are usually required to meet certain application's specific requirements. Bio additives and bio base oils can be obtained from oil bearing crops and according to reports over 350 oil bearing crops are available worldwide [4].

The main focus of this study is to investigate the effects of bio additives on friction and wear produced from locally available oil bearing crops on some selected bio base oils. Extracts of Moringa tree bark *(Moringa oleifera)* (M), Jatropha stem *(Jatropha curcas)* (J), Yellow oleander latex *(Nerium oleander)* (Y), Cocoyam stem *(Colocasia esculenta)* (C) and African elemi tree bark *(Canarium schweinfurthii)* (A), were used as bio additives. While Jatropha seeds oil *(Jatropa curcas)* (J_1), Palm kernel nut seeds oil *(Elacis guineansis)* (P), Soybean seeds *(Glycine soja)* (S), Yellow oleander seeds oil *(Nerium oleander)* (Y_1) and Groundnuts seeds *(Arachis hypogeae)* (G), were used as bio base oil.

MATERIALS AND METHODS

— Preparation of bio base stock & bio additives samples

The raw material for the bio base stock were 5 kg seeds each from the following oil plants, Jatropha, Palm kernel, Soybean, Groundnut and Yellow oleander obtained locally from Kogi State University (KSU) Anyigba, Kogi State, Nigeria. They were properly cleaned to eliminate foreign particles like stones and other impurities. They were dried at room temperature to sufficiently reduce the moisture content, and reduced to smaller sizes using a mortar-pestle and later ground into powder with the aid of a grinding machine to provide a greater surface area for contact with the solvent. Soxhlet extraction process (N-hexane as solvent) in accordance with ASTM D5369-93 was used to extract the oils as bio base stocks

The raw materials for the bio additives were 2 kg dried stems each and 2 litres of latex from the following oil plants stems, Moringa tree barks, Jatropha stems, Yellow oleander latex from fresh stems, Cocoyam stems, and African elemi tree barks obtained from Kogi State University (KSU) Anyigba Kogi State Nigeria. These stems were cut and dried at room temperature to sufficiently reduce their moisture content and properly cleaned to eliminate foreign particles on them. They were pounded in a mortar and ground into powder in a grinding machine as to reduce their sizes and create greater surface area for contact with the solvent. The bio additives were also extracted using Soxhlet extraction method (N-hexane as solvent) in accordance with ASTM D5369-93.

— Characterization of bio additive samples

The bio additives obtained from the plants were characterized using Atomic Absorption Spectrometer Perkin-El-mer model 460 to determine the active elements present in the extracts. A quantity of 2 ml of each of the sample extracts were measured and transferred into beakers and properly coded. The quantity of 10ml each of Nitric acid and HCL were added to each of the beakers and the samples agitated by placing them on a hot plate to raise their temperature to 100 °C for at least one hour. These samples were filtered using a filter to remove all unfiltered soluble within the digested samples after allowing them to cool for 20 minutes. These samples were referred to as digested samples as they were fully ready for atomic absorption spectroscopy (AAS) test. They were one after another introduced into the heating chamber of Perkin-El-mer model 460 atomic absorption spectrometer. Optical and measurement parameters were adjusted for each of the elements detected as to measure the amount of energy absorbed by each of the samples. A detector was used to measure the wavelengths of light transmitted by the sample (the "after" wavelengths) and compared them to the wavelengths which originally passed through the sample (the "before" wavelengths) as each atom has a distinct wavelength. A signal processor then integrates the changes in wavelength, which were readout as peaks of energy on a computer attached to the equipment

— Formulation of the Bio lubricants using Bio additives

The formulation process involved mixing the bio base oils with the bio additives in a required proportion as it done with the convention lubricants. Quantities of bio base oils and the bio additives in pre-determined ratios (as presented in Table 1) were put into a homogenizer and properly blended. Twenty five (25) bio lubricants samples were formulated from the extracted bio base oils after the blending process with the bio additives obtained from the plants been investigated

Table 1: Bio lubricant formulated containing 70 % bio base stocks and 30 % bio additives

Bio additives	Bio Base stock				
	J_1 (70 %)	P (70 %)	S (70 %)	Y_1 (70 %)	G (70 %)
M, (30 %)	J_1M	PM	SM	Y_1M	GM
J, (30 %)	J_1J	PJ	SJ	Y_1J	GJ
Y, (30 %)	J_1Y	PY	SY	Y_1Y	GY
C, (30 %)	J_1C	PC	SC	Y_1C	GC
A, (30 %)	J_1A	PA	SA	Y_1A	GA

BIO ADDITIVES	BIO BASE OILS
M = Moringa tree bark additive	J_1 = Jatropha seed oil
J = Jatropha stem additive	P = Palm kernel nut oil
Y = Yellow oleander latex additive	S = Soybean seed oil
C = Cocoyam stem additive	Y_1 = Yellow oleander seed oil
A = African elemi tree additive	G = Groundnut seed oil

— Evaluation of tribological performance of the formulated bio lubricants

The evaluation of frictional and wear performance of the effects of bio additives on the bio lubricants formulated and reference oils{HDO (SAE 40) and LDO (SAE 30)} was carried out on a Four Balls Rotary tester in accordance with ASTM D 2596 and ASTM G 99(2014) respectively. The Four Balls Rotary tester presented in Figure 1 has the upper holder with one rotating steel ball loaded against three stationary lower steel balls. Prior to conducting the test it was ensured that the surface of the pin and disc were cleaned properly to be free from dirt and debris. All contact areas were submerged in the lubricant and the test, pressures varied from 10 N/mm^2 - 50 N/mm^2 through a hydraulic system in steps of 10 N/mm^2. The ball rotates at 60 rpm through a variable speed drive motor of 2 hp/240 v with a speed range of 60-3000 rpm. The rotation was central along the symmetry axis of both the upper and the lower holders. Piezo electric sensor measured friction force as the rotating disc was heated to 300 ^{0}C, the temperature and rpm were displayed digitally. The applied load was varied from the ranges of 10 N - 50 N, starting with 10 N to obtain the corresponding co-efficient of frictions. While the wear characteristic (wear depth) was measured with high accuracy load cells and values indicated electronically on an indicator as the critical pressures that lead to wear were observed.

Figure 1: Pin-On-Disc Tribotester Set Up
1-LCD; 2-Pin-on-disk assembly; 3-Electric motor; 4-Amplifier/signal processor

RESULTS AND DISCUSION

The results characterization of bio additives obtained from Moringa tree bark (M), Jatropha stem (J), Yellow oleander latex (Y), Cocoyam stem (C) and African elemi tree bark (A) are presented in Table 2. These elements present in the bio additives were similar to those present in conventional additives as reported by Azmi et al. (2016) and Atiya (2013) suggesting that Moringa tree bark, Jatropha stem, Yellow oleander latex, Cocoyam stem and African elemi tree bark extracts can be used as lubricant additives as their functions or actions has the additives qualities of detergent, dispersant, anti- wear, anti-foaming, anti-oxidant, friction modifier, anti-rust, anti-corrosion additives. The authors stated that these elements are usually utilized in engine oils which act as an anti-wear or friction reduction media which formed protective film by physical or chemical absorption to the surface of the metals in contact.

Table 2: Bio additives basic elements obtained by Atomic Absorption Spectroscopy

Elements	Bio additives				
	M	J	Y	C	A
Fe	0.0342	0.0923	0.0581	0.0769	0.1777
Ni	0.0111	0.0222	0.0210	0.0439	0.0034
Cu	0.0015	0.0006	0.0004	0.0046	0.0062
Pb	0.5816	0.4836	0.2230	0.1313	0.5441
Mg	0.0141	0.0408	0.0064	0.0084	0.0157
Zn	0.0004	0.0107	0.0039	0.0439	0.0055
Mn	0.0332	0,0370	0.0248	0.0208	0.0132

— Friction Performance of the Bio Lubricants

Figures 2-6 show the effect of applied load and lubrication condition on the coefficient of friction (COF) at 30 rpm for bio lubricants formulated and reference oils. Coefficient of friction increased steadily with applied load for all the lubricants. Similar results were obtained by [4] while investigating the effect of load on COF of lubricating oils. Light duty oil (LDO) presented the highest COF while heavy duty oil (HDO) presented the lowest COF in all loads. At lower loads the trend of COFs of the formulated bio lubricants (Jathropha seed oil (J_1 as base oil) were (HDO) < (J_1M) < (J_1J) < (J_1Y) = (J_1C) = (J_1A) < (LDO), while at higher loads were (HDO) < (J_1Y) = (J_1A) < (J_1J) < (J_1M) = (LDO) < (J1C). It implies that at lower load bio lubricant J_1M gave a lower value of COF, while at high load the bio lubricant J_1Y gave higher value of COF. Higher value of COF indicates high friction resistance which can probably lead to more wear. In Figure 3 the bio base oil (P) blended with bio additives and reference oils at lower loads exhibited COF as (HDO) < (PM) = (PJ) = (PY) = (PA) < (PC) < (LDO) while at higher loads were (HDO) < (PM) < (PC) < (PY) = (PA) < (PJ) = (LDO). The similar trend was observed for bio lubricants produced from bio base oil and reference oils as (Figure 4) (HDO) = (SC) < (SY) = (SA) < (SJ) = (SM) < (LDO) and at higher loads were (HDO) < (SM) = (SC) < (SY) = (SA) = (LDO) < (SJ).

The COFs for the bio lubricant formulated from bio base oil Y_1 and reference oil (Figure 5) were (HDO) = (Y_1A) < (Y_1J) = (Y_1C) < (Y_1Y) < (Y_1M) < (LDO) while at higher loads were (HDO) < (Y_1J) < (Y_1C) < (Y_1Y) < (LDO) < (Y_1A) < (Y_1M). The trend of COFs (Figure 6) were (HDO) < (GC) < (GA) < (GY) < (GJ) < (GM) < (LDO) and (HDO) < (GA) < (LDO) < (GC) < (GY) = (GJ) = (GM). at lower and higher respectively, for the bio lubricants formulated from bio base oil G. The coefficient of friction of the formulated bio base oils ranged from 0.0815 - 0.09. These values were within established standard range of 0.07 - 0.09 for lubricating oil.

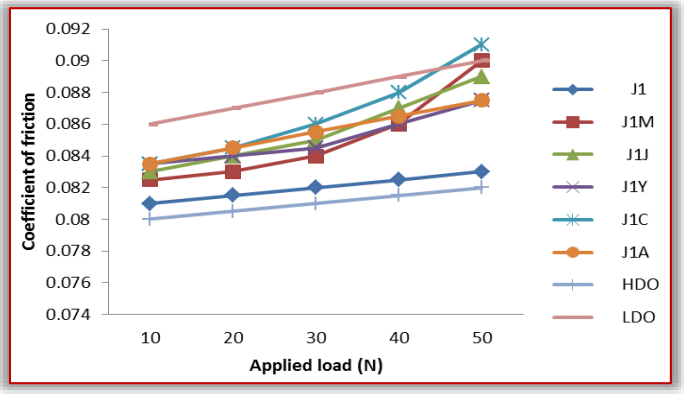

Figure 2: Effect of Applied Load and Lubrication Condition on the Coefficient of Friction at 30 rpm for blended (J_1) oil, pure (J_1) oil and reference oils.
J_1 = Bio base oil from Jatropha seed; J_1M = Mixture of Jatropha seed oil and Moringa tree additives J_1J = Mixture of Jatropha seed oil and Jatropha stem additives J_1Y = Mixture of Jatropha seed oil and Yellow Oleander latex additives; J_1C = Mixture of Jatropha seed oil and Cocoyam stem additives; J_1A =Mixture of Jatropha seed oil African elemi tree additives; HDO = Heavy duty oil; LDO = Light duty oil.

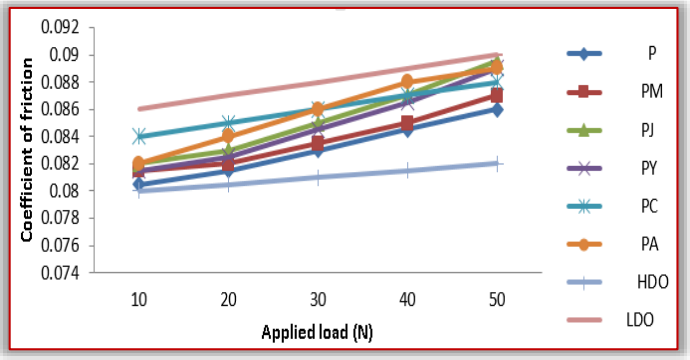

Figure 3: Effect of Applied Load and Lubrication Condition on the Coefficient of Friction at 30 rpm for blended (P) oil, pure (P) oil and reference oils.
P = Bio base oil from Palm kernel nut; PM = Mixture of Palm kernel nut oil and Moringa tree additives; PJ = Mixture of Palm kernel nut oil and Jatropha stem additives; PY =Mixture of Palm kernel nut oil and Yellow Oleander latex additives; PC = Mixture of Palm kernel nut oil and Cocoyam stem additives, PA = Mixture of Palm kernel nut oil African elemi tree additives; HDO = Heavy duty oil; LDO = Light duty oil

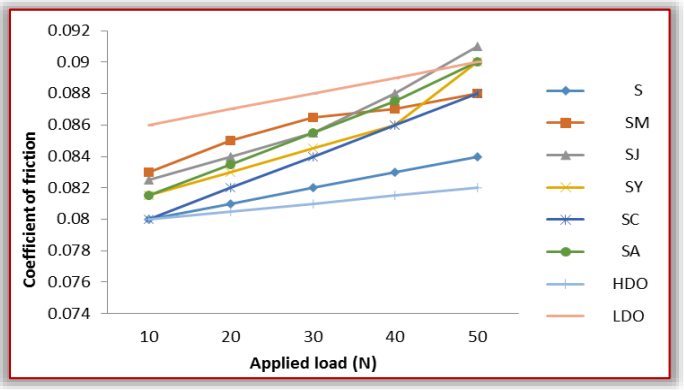

Figure 4: Effect of Applied Load and Lubrication Condition on the Coefficient of Friction at 30 rpm for blended (S) oil, pure (S) oil and reference oils.
S = Bio base oil from Soybean seed; SM = Mixture of Soybean oil and Moringa tree additives; SJ = Mixture of Soybean oil and Jatropha stem additives; SY= Mixture of Soybean oil and Yellow Oleander latex additives; SC= Mixture of Soybean oil and Cocoyam stem additives; SA = Mixture of Soybean oil African elemi tree additives; HDO = Heavy duty oil; LDO = Light duty oil

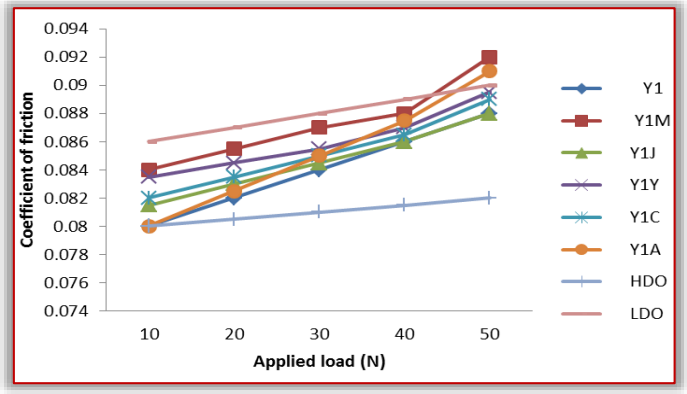

Figure 5: Effect of Applied Load and Lubrication Condition on the Coefficient of Friction at 30 rpm for blended (Y_1) oil, pure (Y_1) oil and reference oils.
Y_1 = Bio base oil from Yellow oleander seed; Y_1M = Mixture of Yellow oleander seed oil and Moringa tree additives; Y_1J = Mixture of Yellow oleander seed oil and Jatropha stem additives; Y_1Y = Mixture of Yellow oleander seed oil and Yellow oleander latex additives; Y_1C = Mixture of Yellow oleander seed oil and Cocoyam stem additives; Y_1A = Mixture of Yellow oleander seed oil and African elemi tree additives; HDO = Heavy duty oil; LDO = Light duty oil

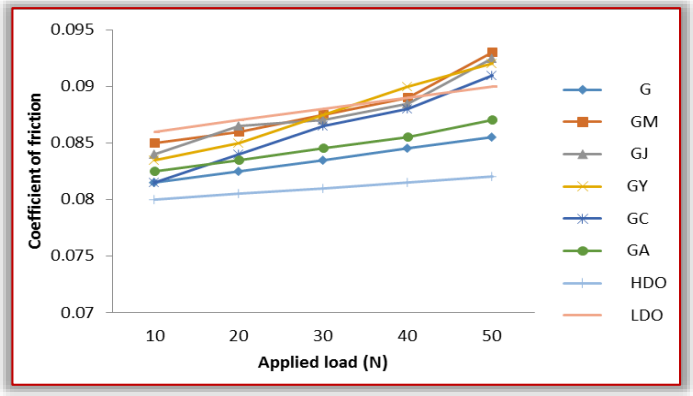

Figure 6: Effect of Applied Load and Lubrication Condition on the Coefficient of Friction at 30 rpm for blended (G) oil, pure (G) oil and reference oils.
G = Bio base oil from Groundnut seed; GM = Mixture of Groundnut oil and Moringa tree additives; GJ = Mixture of Groundnut oil and Jatropha stem additives; GY = Mixture of Groundnut oil and Yellow oleander latex additives; GC = Mixture of Groundnut oil and Cocoyam stem additives; GA = Mixture of Groundnut oil and African elemi tree additives; HDO = Heavy duty oil; LDO = Light duty oil

These results depict that the lubrication regime that existed during the experiment was boundary lubrication, with COF less than 0.1, as the COF for boundary lubrication normally within the range of 0.001 to 0.2 [6]. Generally LDO presented the highest COF at most loads due to its lower viscosity while HDO had lowest COF as it is the most viscous. These trends were similar to those results from earlier researchers which are at lower loads friction on contact area are reduced while at higher loads the friction increased. Lower resistance to wear also presents higher COF [3].

The analysis of variance for coefficient of friction of formulated bio base oils indicated that there was significant difference on the effect of bio addition of bio additives on the formulated bio lubricant at 5 % significant level. The hypothesis (Ho) was that if F ≤ Fcrit then there is no change in the coefficient of friction of the formulated bio lubricant. The other hypothesis (Ha) was that if F> Fcrit then there is

significant change in coefficient of friction of the formulated bio base oils with the addition of additives into each of the bio base oils. It is obvious that there was significance difference in the coefficient of friction with the bio addition to the bio additive to the base oils as F =57.81651 > Fcrit = 2.866081.

— Wear Performance of the Bio Lubricants

Figures 7-11 show the effect of applied pressure and lubrication condition on wear depth at 60 rpm with varied pressure of 10 – 50 N/m^2 for the formulated bio lubricants and reference oils. It was observed that the wear depth increased with increase in applied pressure for all the formulated bio base oils and reference oils. Wear depth data were different for the different formulations due to the concentration of the elements present in the bio additives in the formulated bio lubricants. For Jathropha oil (J_1) blended with bio additives at lower pressures using speed of 60 rpm, the wear depth (Figure 7) trends were (HDO) < (J_1M) = (J_1J) = (J_1Y) = (LDO) < (J_1C) < (J_1A). While at higher pressures were depth trends were (HDO) = (J_1M) < (J_1J) = (J_1Y) = (J_1C) = (J_1A) < (LDO). Similar trends of wear depths were observed for bio lubricants formulated using bio base oils from Palm kernel (P), Soya beans (S), Yellow oleander (Y) and Groundnut oil (G). At lower pressure the wear depth (Figure 7-11) trends were (HDO) < (LDO) = (PM) = (PJ) = (PY) < (PC) = (PA), (HDO) < (SM) = (SJ) = (SY) < (LDO) = (SC) < (SA), (HDO) < (Y_1M) < (Y_1J) = (Y_1Y) = (LDO) < (Y_1C) < (Y1A), and (HDO) < (GM) < (GJ) = (GY) < (GC) < (GA) < (LDO) for Palm kernel (P), Soya beans (S), Yellow oleander (Y) and Groundnut oil (G)base oils respectively. While the wear depths trends at higher pressure (HDO) < (PA) = (PC) < (PY) = (PJ) = (PM) < (LDO), (HDO) < (SM) < (SJ) = (SY) < (SC) = (SA) < (LDO), (HDO) < (Y_1Y) < (Y_1C) < (Y_1A) = (Y_1J) < (Y_1M) < (LDO) and (HDO) < (GM) = (GJ) = (GY) = (GC) < (GA) < (LDO).

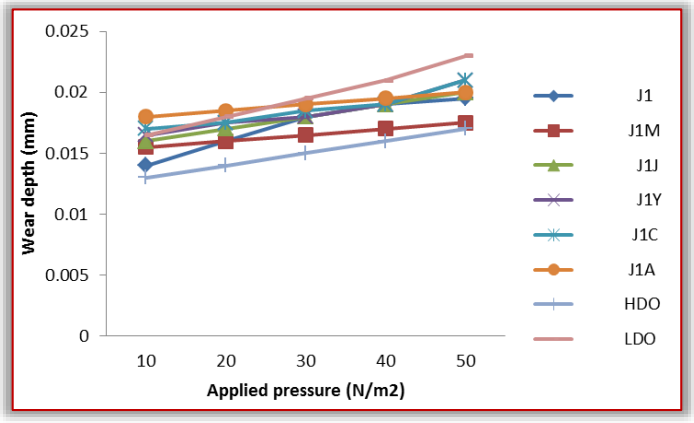

Figure 7: Effect of Applied Pressure and Lubrication Condition on Wear Depth at 60 rpm for blended (J_1) oil, pure (J_1) oil and reference oils.
J_1 = Bio base oil from Jatropha seed; J_1M = Mixture of Jatropha seed oil and Moringa tree additives; J_1J = Mixture of Jatropha seed oil and Jatropha stem additives; J_1Y = Mixture of Jatropha seed oil and Yellow Oleander latex additives; J_1C = Mixture of Jatropha seed oil and Cocoyam stem additives; J_1A = Mixture of Jatropha seed oil African elemi tree additives; HDO = Heavy duty oil; LDO = Light duty oil

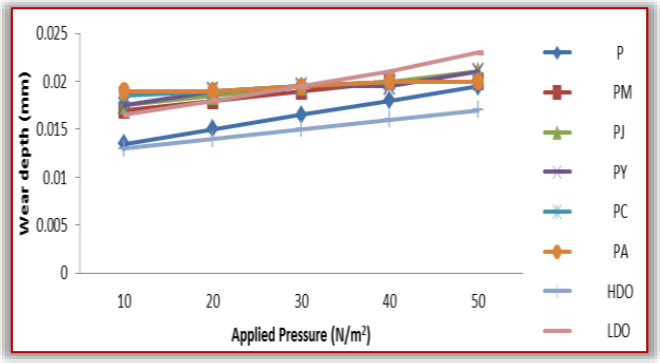

Figure 8: Effect of Applied Pressure and Lubrication Condition on Wear Depth at 60 rpm for blended (P) oil, pure (P) oil and reference oils
P = Bio base oil from Palm kernel nut; PM = Mixture of Palm kernel nut oil and Moringa tree additives; PJ = Mixture of Palm kernel nut oil and Jatropha stem additives; PY = Mixture of Palm kernel nut oil and Yellow Oleander latex additives; PC = Mixture of Palm kernel nut oil and Cocoyam stem additives; PA = Mixture of Palm kernel nut oil African elemi tree additives; HDO = Heavy duty oil; LDO = Light duty oil

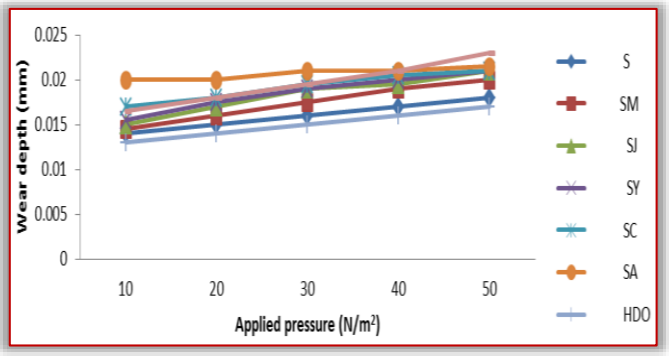

Figure 9: Effect of Applied Pressure and Lubrication Condition on Wear Depth at 60 rpm for blended S oil, pure (S) oil and reference oils.
S = Bio base oil from Soybean seed; SM = Mixture of Soybean oil and Moringa tree additives; SJ = Mixture of Soybean oil and Jatropha stem additives; SY = Mixture of Soybean oil and Yellow Oleander latex additives; SC = Mixture of Soybean oil and Cocoyam stem additives; SA = Mixture of Soybean oil African elemi tree additives; HDO = Heavy duty oil; LDO = Light duty oil

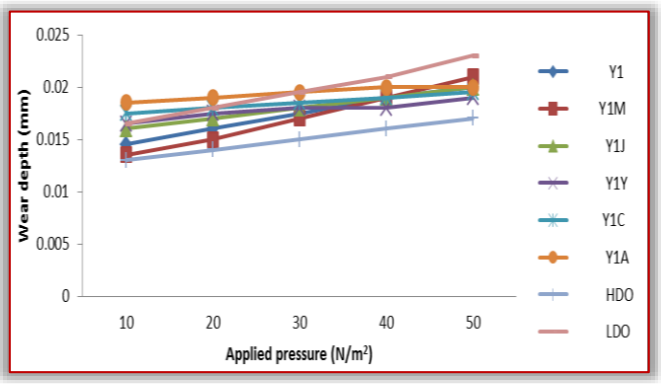

Figure 10: Effect of Applied Pressure and Lubrication Condition on Wear Depth at 60 rpm for blended Y_1 oil, pure (Y_1) oil and reference oils.
Y_1 = Bio base oil from Yellow oleander seed; Y_1M = Mixture of Yellow oleander seed oil and Moringa tree additives; Y_1J = Mixture of Yellow oleander seed oil and Jatropha stem additives; Y_1Y = Mixture of Yellow oleander seed oil and Yellow oleander latex additives; Y_1C = Mixture of Yellow oleander seed oil and Cocoyam stem additives; Y_1A = Mixture of Yellow oleander seed oil and African elemi tree additives; HDO = Heavy duty oil; LDO = Light duty oil

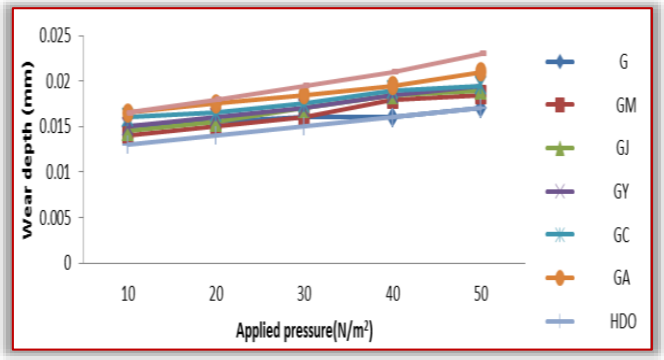

Figure 11: Effect of Applied Pressure and Lubrication Condition on Wear Depth at 60 rpm for blended G oil, pure (G) oil and reference oils.
G = Bio base oil from Groundnut seed; GM = Lubricant mixture of Groundnut oil and Moringa tree additives; GJ = Mixture of Groundnut oil and Jatropha stem additives; GY = Mixture of Groundnut oil and Yellow oleander latex additives; GC = Mixture of Groundnut oil and Cocoyam stem additives; GA = Mixture of Groundnut oil and African elemi tree additives; HDO = Heavy duty oil; LDO = Light duty oil

The wear decreases with increase in viscosity as HDO been more viscous gave the lowest wear depth in the trend. All other oils with lesser viscosity showed increase in wear depth. In the trends the wear depth varied in the formulated bio lubricant. This was confirmed by the analysis of variance that there was a significant effect on wear depth for the formulated bio lubricant with the addition of the bio additives at 5% significant level. The F calculated (7.3268) was greater than F critical (2.689628) which clearly shows that the bio additives have significant effect on the formulated bio base oils. Pressure increase led to increase in contact pressure between the disc and the test sample, thus increased wear depth. The wear depth values for formulated bio base oils ranged from 0.0135 - 0.0210 mm and. these values were within those of the two reference oils (0.0165 - 0.023) mm for light duty (LDO) and 0.013 - 0.017 mm for heavy duty (HDO) used. Lesser wear depths were exhibited in the formulated bio lubricants when compared with light duty (LDO) reference oil and the values of 0.02 - 0.05 mm reported by [6] for Jatropha seed oil. The anti-wear elements such as Cu, Pb, and Zinc which were present in the extract of the selected bio additives has contributed to the reduction of wear in the test carried out. However, the values of wear depth obtained were higher than the wear depth for heavy duty oil (HDO). This implies that the bio lubricants are not suitable for heavy duty vehicles except further treatment are provided for that purpose. The additive in a lubricant is a minimum of one but when present as a package it would consist of many additives serving different functions. Our formulated bio lubricants as a package has many lubricant enhancement properties which were notably viscosity index improvers, friction modifiers, anti -wear agents, rust and corrosion inhibitors, foam inhibitors, detergents, extreme pressure and anti-oxidation additives.

CONCLUSIONS

The following conclusions were drawn

- These bio additives obtained from Moringa tree bark, Jatropha stem, Yellow oleander latex, Cocoyam stem and African elemi tree contain Iron (Fe), Nikel (Ni), Copper (Cu), Lead (Pb), Magnesium (Mg), Zinc (Zn) and Manganese (Mn) as active elements which are also found in conventional lubricant additives.
- The bio-additives were found to improve coefficient for bio lubricants formulated from groundnut oil, yellow oleander seed oil and Jatropha oil.
- The wear depths in the evaluation of the formulated bio lubricants were different and increased as the applied loads were increased. Moreover, the wear depth for the formulated bio base oils using groundnut oil, yellow oleander seed oil and Jatropha oil were better than the reference oils.

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[1.]R–V. BRĂCĂCESCU, [2.]Carmen BRĂCĂCESCU, [2.]Oana–Diana CRISTEA

ASPECTS REGARDING IDENTITY MANAGEMENT USING BLOCKCHAIN

[1.]Politechnica University Bucharest, Bucuresti, ROMANIA
[2.]INMA Bucharest, ROMANIA

Abstract: In order to develop technologies that capitalize on the concept of digital identity, it is necessary to increase the security of the systems, their decentralized character, the immutability and the control of the user to his private data. A digital identity management model is traditionally interpreted as a tripartite model consisting of an end–user, an identity provider and a service official. The latest and most modern model is the Self–Sovereign Identity (SSI) model, which no longer uses the identity and service providers and aims the users to regain control over their identities, gives them the opportunity to share only the data they want to share and facilitates access to various services and applications. The article presents the major models of identity management, focusing on the recent approach, namely SSI, which operates blockchain technology and its advantages.

Keywords: identity management, models, blockchain, self–sovereign identity, decentralized

INTRODUCTION

Digital identity is the representation of an entity (a person, an organization, a device) in the digital environment and consists of a unique identifier and other associated attributes. The evolution of digital identity and identity management models over time has been based on meeting three main requirements: security (data of user identities must be protected), control (the holder of digital identity must maintain control over his private data, he decides who can see them, access and for what purpose) and portability (users must be able to use their digital identity any time and not be depend on a specific provider) *(Laurent et al., 2015; White et al., 2019)*.

With the advance of information technology more and more applications, services, smart devices appered that require users in one way or another to create an account. This generated to many credentials for users to be able to manage.

It is also important to note that all information about a user associated with an account must be well kept and secured by service providers or products, respecting certains rules of protection and maintaining their privacy. In this regard, the General Data Protection Regulation (GDPR), which includes all aspects of the handling of personal data, for which consent is absolutely necessary, has already been implemented in the European Union since 2018, including very high sanctions for individuals, organizations, companies that do not comply with these provisions.

Globally, identity theft has become one of the most common cybercrimes in the digital world and has led to numerous frauds, causing huge financial losses and, in some cases, escalating to the point where it could endangers people's lives *(Cameron, 2015)*.

Taking into consideration all the above, the article presents a new approach to digital identity management, namely, state–of–the–art technology, blockchain.

MATERIALS AND METHODS

A digital identity management model can traditionally be interpreted as a tripartite model consisting of an end user, an identity provider and a service provider.

The end user is the entity that has a digital identity and wants to take different actions using it. The Identity Provider (IdP) is the entity that registers new users, manages digital identities and performs the authentication process. In some cases, it is also possible that the IdP verifies the veracity of the identity provided by the user with the help of an identity card, proof of residence or even with a simple proof of the receipt of an e–mail. The Service Provider (SP) is the entity that provides users with a service, usually a web service, and relies on the IdP to verify their identities.

In the literature *(L'Amrani et al., 2016); Dunphy and Petitcolas, 2018; Goodell and Aste, 2019)* there are mentioned five main identity management models: Isolated Identity Model (Silo), Centralized Identity Model, Federated Identity Model, User–Centric Identity Model and Self–Sovereign Identity Model (SSI).

— Isolated Identity Model, illustrated in Figure 1, is a standard identity management model.

It is based on the user's memory in the sense that he needs to know his identity data for each service provider. The user must remember all the identifiers (IDs) and all the credentials (passwords) generated for all the services he wants to benefit from. The attributes associated with identifiers are managed separately by each service provider. The control over the identities belongs entirely to the service providers, they assume the responsibility for each user. Currently, there are a lot of Web services that use the Isolated Identity Model. The disadvantage of this type of model is related to the large number of authentication data, passwords, which a user must store. For this reason, some users prefer to use the same password for multiple accounts, which can lead to security issues.

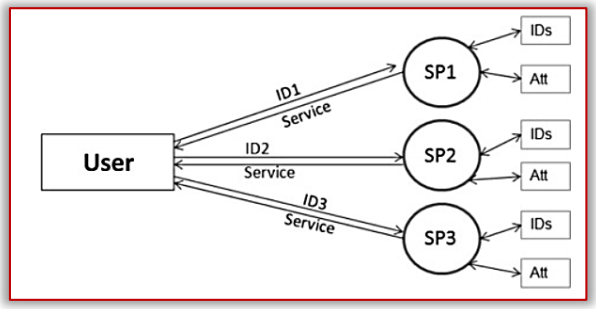

Figure 1 – Isolated Identity Model

— The Centralized Identity Model introduces an Identity Provider (IdP) that centralizes the digital identity management process (Figure 2).

The user can authenticate to service providers (SP) using a single identity, with the same credentials, without having to repeat the authentication for each new service provider requested.

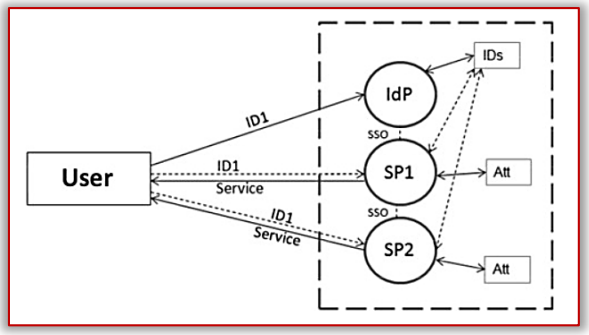

Figure 2 – Centralized Identity Model

This results in the Single–Sign On (SSO) mechanism through which a single authentication instance provides access to all SPs that belong to the same Identity Provider. The ease of use is undeniable compared to the Isolated Identity Model, but the centralized model still has some inconvinients. Disclosing an identifier along with the associated credentials is sufficient to provide unauthorized access to all services. In addition, the centralized layout of this model does not make it suitable for a large number of users or SPs.

— Federated Identity Model, illustrated in Figure 3, assumes that IdPs and SPs group together to form a federation of identities and are linked by relationships of trust due to trade agreements and a common technology platforms.

This federation is called the Circle of Trust (CoT). As with the centralized model, SSO mechanisms can be implemented, the user can authenticate once with the IdP to access the services of SPs that are members of the CoT. The user accessing an SP is referred to by the SP under a pseudonym. In fact, all data exchanges between SP and IdP related to a user are based on pseudonyms. The Federated Identity Model is suitable for a large number of uses and SPs, being interesting in the context of distributed and collaborative services. As in the previous model, the user sends the attributes and identifiers of the IdPs, the service providers are obliged to trust them.

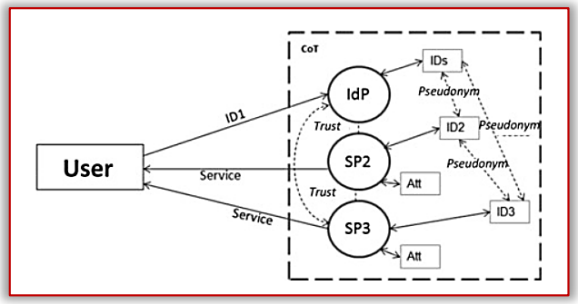

Figure 3 – Federated Identity Model

— The User–Centric Identity Model gives the user complete control over his personal attributes.

It has, using an IdP of its choice, an electronic identity portfolio and sometimes an identity selector. Upon request to access the services, the user can select an identity and decide whether to provide certain attributes. Service providers act individually in this model and may, although with some difficulties, provide collaborative services. They are increasingly inclined to propose user authentication, leaving them to decide on the choice of IdP. An example is the case of Yahoo, which offers the possibility to authenticate users using their Facebook or Google account. However, the User–Centric Identity Model still depends on the IdP, is not a complete user–based model, and requires very good integration of all components of the assembly.

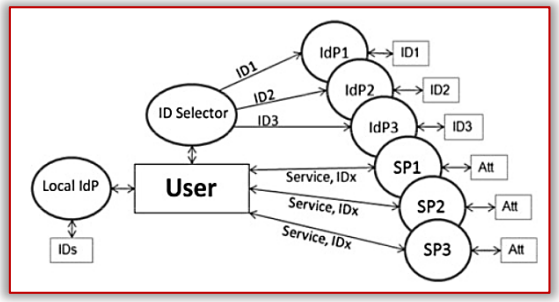

Figure 4 – User–Centric Identity Model [17]

The latest model and the most modern one is the Self–Sovereign Identity (SSI) model. It goes a step further than the user–centric model and eliminates the need for an external identity provider. The end–user gains full control over his identity, being his own identity provider, and because of this, the danger of identity theft is diminished *(Hileman and Rauchs, 2017; Der et al., 2018; Vadapalli, 2020)*.

Regardless of the model, identity management solutions should follow the laws of identity, described by Cameron (2005), an evaluation framework used to identify the pros and cons of digital identity solutions.

This laws suggest that identity information should be disclosed only to legitimate parties, who have this right and only with the user's consent. Moreover, the information collected and stored should be minimal, according to the needs of the service. End–users should be wise to interact with the funds and be aware of the implications of the actions taken. They should be able to share identity information either in private or in public.

From a legal point of view, identity management solutions must respect the data confidentiality and security in accordance with the regulations in force. For example, the solutions that are implemented in European Union countries must comply with the GDPR, a set of data protection policies that appeared in May 2018. Similar principles exist outside Europe, for example, the Digital ID & Authentication Council of Canada (DIACC) has introduced ten principles that a digital identity ecosystem should follow.

Blockchain is essentially a distributed database of records or public information of all transactions or digital events that have been executed and shared between the participating parties. Blockchain can be interpreted as a public distributed ledger, containing information about transactions, in a verifiable and permanent manner, managed by a peer–to–peer network. Each transaction made in the public register is validated by the consensus mechanism. Once entered, the information cannot be deleted or altered *(Allen, 2016)*. It is important to note that the technology called Distributed Ledger Technology and Blockchain technology are not synonymous, the last oane mentioned being a distributed registry implementation that in addittion uses cryptography *(Yaga et al., 2018)*.

From an architectural point of view, Blockchain is a growing list of records called blocks, which communicate with each other through encrypted messages *(Zheng et al., 2017)*. As a data structure, a blockchain is a simple linked list, in which the connections between the blocks are made by a hash. Each block contains its own cryptographic hash and the one of the previous block, a timestamp and transaction data.

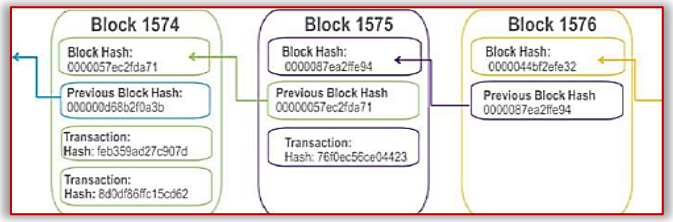

Figure 5 – Blockchain sequence example [23]

Every participant in a Blockchain network, every connected device, server, mobile phone, computer, is called a node. There are several types of nodes, the most important are Full Nodes, Light Nodes or SPV (Simple Payment Verification) and Mining Nodes.

Full Nodes contain a copy of the entire blockchain, information about all transactions made, and all blocks created. They require sufficient resources and a amount large memory, hundreds of gigabytes. With their help, any new entered transaction, any modification and any added block are validated. Full Nodes provide the consensus mechanism by which all changes required require the agreement of some or all of the nodes in order to be accepted *(Mühle et al., 2018)*.

Light Nodes have the same purpose as Full Nodes, but do not store the entire history of the blockchain, they usually contain a block header used to further query a Full Node in the process of verifying a transaction. Light Nodes do not require as many resources as Full Nodes, on which they are dependent. Light Nodes were designed to increase the network capacity and the level of decentralization *(Mühle et al., 2018)*.

Mining Nodes are the nodes that create other blocks for the network. To add a new block it is necessary to calculate its hash, practically to solve a problem of cryptography by brute force. The first node that solves this problem and receives approval from a Full Node can add the new block.

RESULTS

Decentralization is one of the most important features of the Blockchain. In contrast to centralization, within the blockchain the central authority is no longer required. Consensus algorithms are used to maintain the consistency of the data in the distributed network. Persistence is another feature of a Blockchain system. Transactions can be validated quickly and it is almost impossible for transactions to be deleted or withdrawn once they are included in the blockchain *(Hilleman & Rauchs, 2017)*.

The blockchain has an accelerated dynamic of changing its status, new transactions can continuously occur. Therefore, its large publicly shared registers need an efficient, real–time, functional, reliable and secure mechanism to ensure that all transactions that take place on the network are authentic and that all participants agree with changes made to the status of the register. This important task is accomplished by the consensus mechanism, which is a set of rules that decides on the contributions of different blockchain participants *(Yaga et al., 2018)*. There are different types of consensus mechanism algorithms that work on different principles: PoW (Proof of Work), PoS (Proof of Stake), PBFT (Practical Byzantine Fault Tolerance), DpoS (Delegated Proof of Work).

Blockchains can be classified into permissionless or public and permissioned or private. In a Permissionless blockchain, any entity can become a node and can participate in the consensus mechanism. The Permissioned blockchain increases control over the system by limiting participation in the consensus mechanism. Usually, in a Permissioned blockchain only the nodes in a specific organization provide the consensus mechanism. Depending on the application and needs, one type or another can be used. For example, cryptocurrencies such as Bitcoin are Permissionless.

A Smart Contract is an agreement or set of rules that governs a transaction. It is a computer program code stored in the blockchain and which is executed automatically as part of the transactions performed. Smart contracts are entirely digital, being written in various programming languages. This code defines the rules and consequences in the same way as a traditional legal contract, indicating the obligations, benefits and sanctions that could be due to each party in different circumstances. The purpose of using smart contracts is to reduce delays, costs and bottlenecks generated by traditional legal documents, while ensuring a higher level of security.

Digital signatures, based on asymmetric cryptography, are used in the Blockchain to complete the consensus process and to sign Smart contracts. Each user has a key pair, a private key and a public key. The private key is confidential and will be used to sign transactions. The signed digital transactions will be distributed throughout the blockchain network. The digital signature involves two phases of signing and verification (*Yildirim and Mackie, 2019)*. The typical digital signature algorithms used in the blockchain is the ECDSA algorithm, Elliptic Curve Digital Signature Algorithm.

Identity management solutions built using blockchain technology benefit from its intrinsic advantages. It eliminates the need for a central authority to control and manage the system and gives the responsibility back to the user. Some of the problems that occur in centralized systems, such as identity theft and data loss, can be largely solved by using the blockchain. By construction, the blockchain brings transparency in the changes made and the data history cannot be altered otherwise (unless most nodes agree on a change). On the other hand, there are challenges in terms of implementation efficiency and even security.

A blockchain–based identity management solution should allow for the selective storage of identities in the blockchain. Identities must be certified by authorities or other entities in the blockchain. Usually things work as follows. An entity claims an identity through a verifiable claim. This is attested after checking user attributes (eg phone number, e–mail, biometrics). In blockchain identity management, there is a clear distinction between the digital identifier (a value that uniquely identifies an entity) and the attributes associated with it *(Lesavre et al., 2019)*. As unauthorized disclosure of attributes leads to security and confidentiality breaches, their storage (if any) should be carried out in accordance with well–defined principles.

CONCLUSIONS

Identity management is a field that is attracting more and more attention. There is a clear need for platforms to address this growing number of user accounts. Throught the paper, the five major models of identity management were presented: Isolated Identity Model, Centralized Identity Model, Federated Identity.

Model, User–Centered Identity Model and Self–Sovereignty Identity Model. From these, the Self–Sovereign Indentity Model is the one that will be used more and more in the future, due to the increasing in popularity technology on which it is based, blockchain, and due to the principles of data security, control and persistence that is following. Blockchain is one of the top technologies nowadays, which continues to develop and is capable to reform the information technology domain.

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[1.]Ivalina PETROVA

THERMODYNAMIC STUDY ON THE CO–PIGMENTATIOON INTERACTION BETWEEN CYANIDIN 3–GALACTOSIDE AND ROSMARINIC ACID IN MODEL SYSTEMS

[1.] Department of Mathematics, Physics and Chemistry, Technical University of Sofia, Branch Plovdiv, Plovdiv 4000, BULGARIA

Abstract: Interactions between aronia anthocyanins as pigment and rosmarinic acid as copigment were studied. Investigations were done in different temperatures from 20^{0}C to 80^{0}C at heating system and cooling the same system at 80 to 20^{0}C. The system was investigated with high concentration of rosmarinic acid from 1:1 to 1:50 molar ratio. The thermodynamic parameters ΔG, ΔH and ΔS of the system were calculated as function of temperature at heating and at cooling. Obtained results confirmed that the interaction between pigment: copigment complex was destroyed at heating to 80^0 C and with following cooling to 20^{0}C seen reversibility of the copigmentation process.
Keywords: cyanidin; rosmarinic acid; copigmentation; thermodynamic parameters

INTRODUCTION

The production of natural food pigments continues to grow worldwide. Pigments such as anthocyanins, carotenoids, betalains, and chlorophylls have been used to color foods. However, there are challenges related to color losses during food processing, storage, and commercialization due to a low stability of natural pigments compared to synthetic colorants. This review summarizes the most recent studies and patents aimed at enhancing anthocyanin stability in food systems. The stabilizing methods include additions of copigment compounds, such as polymers, phenolic compounds, and metals. In addition, the exclusion of O_2 during processing and storage, hard–panned candy coating methods for blue, green, and brown colors, and various encapsulation techniques were considered. Combining strategies and evaluating new materials capable of stabilizing anthocyanins will enhance their potential for use as value–added natural food pigments [1]. Anthocyanins represent one of the most important and most widespread groups of plant pigments of the class of flavonoids. This group of pigments is responsible for the existence of most of the red, blue, and purple colors in flowers and fruits [2]. Although phenolic copigments are rarely colored, they can still influence color expression in red wine copigmentation. Here, prefermentative agents, such as caffeic and rosmarinic acids, were added as copigments during Cabernet Sauvignon red winemaking. The evolution of colors and polyphenols was analyzed by tristimulus colorimetry and high–performance liquid chromatography–tandem mass spectrometry during brewing and aging periods. The results showed that the addition of caffeic and rosmarinic copigments was beneficial to obtain more saturated and vivid hue of wines. The changes in color were correlated with a significant increase in anthocyanins concentration. Moreover, the results demonstrated that the addition of the two phenolic copigments increased the concentration of total phenols and enhanced the copigmentation effect, indicating improved chromatic intensity and color stability of wines. Therefore, the addition of caffeic and rosmarinic acids is a simple and useful enological technique to obtain red wines with high color quality and aging potential [3].

Zhao et al. [4] study investigated the protective effect and mechanism of action of combined use of rosmarinic acid (RA) and xanthan gum (XG) on the stability of anthocyanins (ACNs) in the presence of l–ascorbic acid (pH 3.0). The addition of RA and XG, alone and in combination, significantly enhanced the color stability of ACNs, and the combined use of RA and XG showed the best effect. According to Eiro et al. [5] intermolecular copigmentation reactions are significantly responsible for the manifold color expression of fruits, berries, and their products. These reactions were investigated with five anthocyanins and five phenolic acids acting as copigments. The stability of the pigment–copigment complexes formed was studied during a storage period of 6 months. The study was conducted using a UV–visible spectrophotometer to monitor the hyperchromic effect and the bathochromic shift of the complexes. The greatest copigmentation reactions took place in malvidin 3–glucoside solutions. The strongest copigments for all anthocyanins were ferulic and rosmarinic acids. The immediate reaction of rosmarinic acid with malvidin 3–glucoside resulted in the biggest bathochromic shift (19 nm) and the strongest hyperchromic effect, increasing the color intensity by 260%. The color induced by rosmarinic acid was not very stable. Copigmentation of anthocyanins accounts for over 30% of fresh red wine color, while during storage, the color of polymeric pigments formed between anthocyanins and proanthocyanidins predominates. Rosmarinic acid and natural extracts rich in hydroxycinnamic acids, obtained from aromatic plants (Origanum vulgare and Satureja thymbra), were examined as cofactors to fresh Merlot wine and the effect on anthocyanin copigmentation and wine color was studied during storage for 6months [6].

Copigmentation has been suggested as a main colour stabilising mechanism in plants protecting the coloured flavylium cation from the nucleophilic attack by the water molecule. In this study influence of phenolic compounds

addition (catechol, 4–methyl catechol, (+)–catechin and gallic acid) on stability of red currant juice anthocyanins (copigment:pigment molar ratio 50:1 and 100:1) during 30 days of storage at 4°C was investigated. Stability of anthocyanins was evaluated through determination of anthocyanins, total colour difference (ΔE*), kinetic parameters and anthocyanin retention [7]. Anthocyanins show low–stability when exposed to different food processing conditions. Copigmentation is one of the main reactions contributing to the in vivo color responsible to the stability of anthocyanins. In the aim of holding the red color, copigmentation effect of organic acids (caffeic, ferulic, gallic and tannic acids) combined with anthocyanins in crude Cabernet Sauvignon (Vitis vinifera L.) grape skin extract at pH values (1.0, 2.0, 3.0, 3.3, 3.5, 3.7, 4.0, 4.5) was evaluated in this research [8]. Interactions between strawberry anthocyanins as pigment and caffeic acid as copigment were studied. Investigations were done in different temperatures from 20°C to 50°C at heating system and cooling the same system at 50 to 20°C. The system was investigated with high concentration of caffeic acid from 1:20 to 1:100 molar ratio. The thermodynamic parameters ΔG, ΔH and ΔS of the system were calculated as function of temperature at heating and at cooling. Obtained results confirmed that the interaction between pigment:copigment complex was destroyed at heating to 50°C and with following cooling to 20°C was not seen reversibility of the copigmentation process [9].

Amzad et al. [10] effect of solvents on recovery of polyphenols from the pink fuji apple skin. Dehydrated apple skin powder was used to evaluate the recovery of selected flavones and rosmarinic acid using water, methanol, acetone, chloroform, aqueous 50% methanol, and aqueous 70% acetone at 40°C. The retrieved extracts were subjected to qualitative and quantitative GC–MS analysis. Similar yield of rosmarinic acid (RA) was obtained in aqueous 70% acetone extracts when the periods of extraction were 2, 4, 6 and 8 hours, respectively.

The reaction of malvin chloride (malvidin 3,5–diglucoside) with a flavonoid compound rutin (quercetin 3–rutinoside) is investigated. Reactions of these molecules are observed through UV–vis absorption spectra, to identify the factors that influence the copigmentation as well as the characteristics of the copigment formed. It is established that the copigmentation process takes place in buffer solutions at a specific pH value and that it is conditioned by the mole ratio and temperature. Copigment formation is defined by kinetic and thermodynamic parameters [11]. The effect of temperature on the stability of the copigmentation complex of strawberry anthocyanin extract as pigment and caffeic acid as copigment was investigated. The system was studied with a high concentration of caffeic acid 1:20 to 1:100 molar ratio. Different temperatures and copigment concentrations were used for the investigated pigment: copigment interaction and kinetic parameters such as activation energy (Ea), z – factor and degradation rates (k) were calculated.

According to the calculated results, at high temperatures (50°C) destruction of the complex was observed. Decreasing the temperature in the range of 20–30°C did not lead to restoration of the complex, indicating irreversibility of the copigmentation process [12].Thermal degradation and color changes of purified strawberry anthocyanins in model solutions were studied upon heating at 85 degrees C by HPLC–DAD analyses and CIELCh measurements, respectively. The anthocyanin half–life values increased significantly due to the addition of rose (Rosa damascena Mill.) petal extracts enriched in natural copigments. Correspondingly, the color stability increased as the total color difference values were smaller for anthocyanins upon copigment addition, especially after extended heating [13].The stability of anthocyanins from Viburnum opulus fruits, in aqueous and ethanolic extracts, stored under darkness for 7 days at different temperatures (2°C, 37°C and 75 °C) and pH values (pH = 3 and 7), was studied here. Results indicate that the storage degradation of anthocyanins followed first–order reaction kinetics under all investigated conditions [14].

MATERIALS AND METHOD

— Chemicals

Chemicals the copigment rosmarinic acid was from Sigma – Aldrich, 98 % (Germany).The reagents used for the McIlvaine buffer pH 3.4 citric acid monohydrate and disodium hydrogen phosphate dodecahydrate, were from Merck (Darmstadt, Germany). The adsorbent resin AmberliteXAD 16N resin was purchased from Sigma Aldrich Co. (St. Louis, MO, USA). All other reagents and solvents used were of analytical grade.

— Plant materials

Aronia fruits were supplied from local growers of aronia fruits, in the stage of full maturity, in august 2020. Fresh fruits were put in polyethylene bags, frozen immediately and stored at – 18°C until extracted.

— Extraction, purification and determination of anthocyanins

Aronia anthocyanins were extracted and purified as described Shikov at al., [13]. Frozen aronia were thawed and manually squeezed in a beaker. The homogenized purée was extracted overnight at 4 °C using methanol acidified with hydrochloric acid (1%, v/v) at a solvent/solid ratio 2.5:1 (v/w). The extraction mixture was filtered and the organic solvent was evaporated under vacuum (30 °C). To remove sugars, salts, and amino acids from the crude extracts, samples were purified using a column (465 × 30 mm i.d.) filled with adsorption resin AmberliteXAD 16N. Prior to sample application, the resin was conditioned and equilibrated by rinsing with 500 ml of methanol and 1000 ml of water, acidified with trifluoroacetic acid (TFA, pH 2). Subsequently, 250 ml of the aqueous strawberry extract were applied and the column rinsed with 1000 ml of

acidified water (pH 2). For elution of the pigments at least 500 ml of a mixture of methanol and acidified water (TFA, pH 2) (95:5, v/v) was applied until the column was colourless. The organic solvent of the eluate was evaporated under vacuum (30 °C). To separate anthocyanins from colourless phenolics, further purification was performed by extracting the aqueous phase three times with the same volume of ethyl acetate. After evaporation and concentration under vacuum (30 °C), the residue was lyophilized for 72 h. The total monomeric anthocyanins were assessed by the pH–differential method. The results were expressed as pelargonidin 3–glucoside equivalents.

— Preparation of model solutions of pigment and co–pigments

Stock solutions of strawberry extract, on the basis of the total anthocyanins, and rosmarinic acid were prepared in McIlvaine buffer (0.1 M, pH 3.4). Model solutions of strawberry anthocyanins (1 x10^{-}4 M) were obtained by mixing equal volumes (5 ml) of the corresponding stock solutions and were left for equilibration (30 min at 25 °C).

— Spectrophotometric measurements

Absorption spectra from 400 to 700 nm were recorded with a Helios Omega UV–Vis spectrophotometer equipped with VISION lite software (all from Thermo Fisher Scientific, Madison, WI, USA) using 1 cm path length cuvettes. Before measurements the samples were thermostated (VEBMLW Prufgepate–Werk Medingensitz Freital, Germany) at 20, 30, 40, 60 and 80 °C, respectively during heating and then for 10 min at 60°C, 40°C, and 20°C during cooling.

— Modelling of thermodynamic parameters

Thermodynamic parameters were calculated according to Petrova et al. [9]. After spectrophotometer measurements the equilibrium constant was calculated by the equation:

$$\ln[(A - A_0|A_0)] = \ln[K] + n \ln C \quad (1)$$

where: A and Ao are the absorption maximum values of the anthocyanin solution with and without co–pigment; C is the molar co–pigment concentration; K is the equilibrium constant and n is the stoichiometric ratio of the reaction. The dependence of ln[(A – Ao)/Ao] on the co–pigment concentration, ln[(A – Ao)/Ao] = f(ln[C]), is a straight line with a slope and intercept equal to n and ln[K].

Gibbs free energy was calculated using the equation

$$\Delta G = -RT\ln Kp \quad (2)$$

where R is the universal gas constant (R = 8.314 J K^{-1} mol^{-1}), T is the absolute temperature (K), ΔG is Gibbs free energy (kJ mol–1), K – equilibrium constant.

The enthalpy was calculated by applying the Vant–Hoff equation:

$$\frac{d \ln K}{d(1/T)} = \frac{-\Delta H}{R} \quad (3)$$

ΔH is enthalpy for the co–pigmentation reaction (kJ mol^{-1}). Once the Gibbs free energy and the enthalpy were obtained, the entropy can be determined by using the following classic thermodynamic equation:

$$\Delta S = \frac{(\Delta H - \Delta G)}{T} \quad (4)$$

where: ΔS is entropy for the co–pigmentation reaction (kJ K^{-1} mol^{-1}).

RESULTS AND DISCUSSION

In this study the model solutions prepared with stoichiometry quantity anthocyanin and variations of copigment change between 1:1 to 1:50 high concentration. The equilibrium constant and calculated thermodynamic parameters are presented in Table 1.

Table 1: Reaction equilibrium constant and thermodynamic parameters of the copigmentation interactions between black chokeberry anthocyanins and rosmarinic acid

Temperature, °C		K	ΔG [kJ.mol^{-1}]	ΔH [kJ.mol^{-1}]	ΔS [kJ.mol^{-1}]
Heating	20	9705,1	–22,74	–27,22	–0,015
	40	4570,88	–21,93	–27,74	–0,018
	60	390,46	–16,02	–28,28	–0,0379
	80	107,15	–12,94	–25,00	–0,036
Cooling	60	400,86	–16,09	–25,78	–0,030
	40	3419,00	–21,17	–27,41	–0,019
	20	6295,06	–21,67	–26,75	–0,017

At 20°C the constant showed the highest value. At the same temperature the Gibbs energy exhibit the most value –22.74 kJ mol^{-1}. At 40°C the Gibbs energy exhibited the similar results. With increase of temperature more den 40°C stability decrease and pigment: copigment couple decompose. At 80°C Gibbs energy is equal to –12.94 kJ mol^{-1}. These results connected with destroy complex system at heating to 80°C and restore at cooling to 20°C.

These results connected with spontaneous process of copigmentation. The enthalpy and entropy changes of the process were negative at all temperatures at heating and at cooling. It can be concluded that such a dependence on temperature is a consequence of the exothermic copigmentation process, ΔH< 0. The negative value of the entropy, ΔS indicates that the couple formation depending of order/disorder of the system.

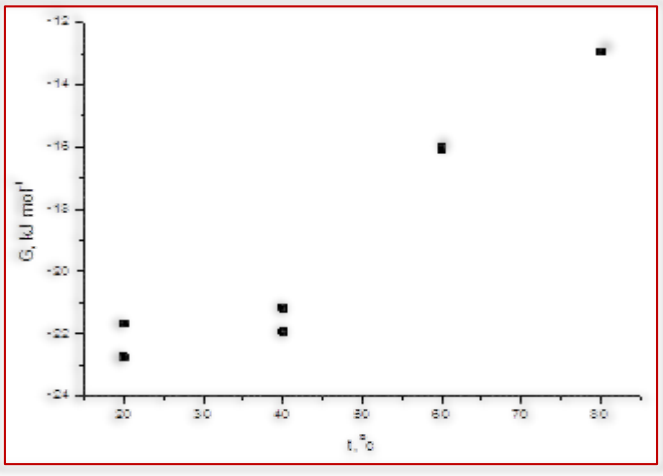

Figure.1. Dependence of thermodynamic parameter Gibbs energies at different temperatures at heating and at cooling

At heating system seen decrease of Gibbs energies in positive values and at cooling the Gibbs energies not restore values and increase more to positive values. Increase Gibbs energies to positive values are proof to decrease stability of investigated pigment: copigment system and in this case connected with destroy of the system.

CONCLUSION

The thermal stability of isolated aronia anthocyanins: rosmarinic acid was provide first by heating system to 80°C and then cooling to 20°C. At the same temperatures destruction was observed and after that the observed complex was restored. The thermodynamic parameters exhibited negative values at all temperatures and this is proof for a stable complex. On the basis of thermodynamic parameters obtained in all temperature range it can be concluded that the process of copigmentation is possible only at temperature 40°C or lower.

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[1.]Elijah G. IKRANG, [2.]Precious O. EHIOMOGUE, [1.]Unwana I. UDOUMOH

HYDRO AND AERODYNAMIC PROPERTIES OF FRUITS AND VEGETABLES: A REVIEW

[1.]Department of Agricultural and Food Engineering, Faculty of Engineering, University of Uyo, NIGERIA
[2.]Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, NIGERIA

Abstract: Hydro and aerodynamic properties of the material to be processed are fundamental and continue to be a challenge for researchers to design a machine appropriately. Mechanical damages to seed at harvesting, transporting, and threshing are major concerns form farmers and farming experts. All the processes of wing transfer, floatation and seed removal from seed mixture and the stalks and husks depend on the behaviour of the seeds in the wind flow. Therefore, it is crucial to determine the physical and aerodynamic properties of various crops to analyzing their behaviour during transport, processing, and precise design of farm equipment and machines to minimize wastes. Physical and aerodynamic properties of agricultural products have been used to precision design of the machinery and different postharvest operations. In this review, hydro and aerodynamic properties of selected agricultural products have been reviewed. Therefore this paper presents highlights and reviews of studies related to the measurements of hydrodynamic and aerodynamic properties of some selected agricultural products. The objective is to study methodologies used and identify future research directions to get a more accurate result. Several papers search from various search engines for scientific articles that are available online. Some keywords and a combination of keywords used in the search process are "hydrodynamic properties", "aerodynamic properties" of fruits and vegetables. The result of the search showed that terminal velocity and drag coefficient of agricultural products have been extensively studied for the designing of air/hydro conveying systems and separation equipment. The result also showed that computer vision and image processing has also been used to detects defects, quality control, classification and sorting of agricultural products.
Keywords: Terminal velocity, Grading, Aerodynamic, Fruits and Vegetables, Sorting

INTRODUCTION

Grading by farmers are usually by experience or through to select either grading by size or by weight (Mokhtar and Firdaus, 2014). This manual sorting techniques will generate some problems such as error in grading, delaying task for sorting because humans cannot work continuously and if there is so many tons, farmers will pay more workers to do the job. The need to develop efficient automated grading system cannot be over emphasize. However this is not without limitation due to irregular shape and sizes of fruits and vegetables. Fruit graders that employ near infrared technologies are expensive and more importantly the calibration and maintenance requirement remain outside the skills of packing house staff (Jordan and Clark, 2004).

The food industry has long utilized air and water to transport products from one location to another, especially raw products. Likewise, a gas or fluid can be utilized to separate a desirable product or products from undesirable materials. When designing systems to work with a specific food material, one must know about the aero and hydrodynamic characteristics of the material. The characteristics, or primary properties, that govern the product behavior in air or water are the drag coefficient and the terminal velocity (Fletcher, 1975).

Terminal velocity and drag coefficient of agricultural products are important and required for the designing of air/hydro conveying systems and the separation equipment (Jalgaonkar *et al.*, 2017).

Terminal velocity is a complex function of fruit shape, fruit size, both water and fruit temperature, and density (Garavand *et al.*, 2010; Kheiralipour *et al.*, 2010; McGinley and Brigham, 1989)

The physical properties such as density, shape size, are required for calculating the terminal velocity and drag coefficient of the agricultural produce (Garavand *et al.*, 2010).

Terminal velocity of fruits is a maximum velocity that each fruit can reach in specific medium (Mohsenin, 1986). Terminal velocity of any falling object is reach when the net force in the downward direction (net body force) is balanced by air resistance (drag force) (McGinley and Brigham, 1989)

As world market for fruit and produce become more sophisticated and technology continues to provide means to measure product quality, there is a corresponding market pull for produce with higher quality levels. Demand from consumer for quality produces, consistent behaviour of machines in comparison with humans, the insufficiency of labour and an attempt to reduce labour costs are the main motivations of automated packing and sorting system in the past decades (Bally, 2006)

According to Jordan and Clark (2004), the right approach to fruit sorting is to use the terminal velocity fruit moving in a fluid that has a density above or below the target density. Density, a good indicator of fruit dry matter thus become an interesting tool for fruit quality sorting because of its inherent lower cost and simpler operation (Richardson *et al.*, 1997). Sorting product based on density is not new, potato, citrus, blueberries and tomatoes have been sorted by floatation techniques for quality or defects (Bajema, 2001; Jordan and Clark, 2004; Wilson and Lindsay, 1969).

Fruit with different terminal velocities will reach different depths after flowing a fixed distance in a flume and may be separated by suitably placed dividers. This approach could use water as a sorting medium, which provides huge advantages in terms of the resulting low corrosion and

disposal difficulties, and the fact that it does not need any density adjustment. Moreover, this approach allows purely mechanical setting of the separation threshold by adjusting the divider positions and no change in fluid density is required. Garavand *et al.* (2010) model the terminal velocity of tomato in water column to determine if there was a potential for terminal velocity methods as a practical approach that could be used in sorting unit operation in tomato processing.

The result showed that fruit density created a considerable influence on terminal velocity while the parameters such as fruit volume, shape factor had small effect on the terminal velocity. It was concluded that in any sorting systems, difference in terminal velocity of tomatoes could be addressed as a crucial factor for designing sorting systems. Drag coefficient is used to quantify drag or resistance of an object in a fluid environment such as air or water. Drag coefficient is associated with surface area.

SEPARATION TECHNOLOGIES

Fruits with approximately constant volume and different densities have different terminal velocities and can be used in separation technology (Mirzaee *et al*., 2008). Several non-destructive methods are available to improve the quality assessment of fruits and vegetables after harvest.

X-ray, accelerometer, electronic nose, nuclear magnetic resonance, and near-infrared spectroscopy are some of the non-destructive available quality assessment technology (Costell and Duran, 2002; Nordey *et al*., 2019). X-ray is used to measure the size, shape colour, and external defects by image analysis (Lakshmi *et al*., 2017).

The limitation of using terminal velocity and drag force is that they do not detect the inner quality of the fruits and vegetable. Another limitation and challenges is the fact that the shapes and sizes of fruits and vegetables varies greatly from one to another. The above limitation can be overcome by the use of computer vision and image processing.

COMPUTER VISION AND IMAGE PROCESSING

The detection of defects, quality control, classification and sorting of the product are some of the major applications of machine vision system. Computer vision and image processing systems not only recognize size, shape, colour, and texture of objects, but also provide numerical attributes of the objects or scene being image. Image processing and image analysis are recognized as being the core of computer vision (Krutz *et al*., 2000). Computer vision system generally consists of five basic components: illumination, a camera, an image capture board, computer hardware and software (Wang and Sun, 2002). Figure 1 shows computer vision system for the by Bio-inspired Vision Fusion for Quality Assessment of Mango.

The vision system directly measures the fruits without physical contact with it. Unfortunately this method will not be suitable for small and medium growers because the system is very expensive (Wang and Sun, 2002).

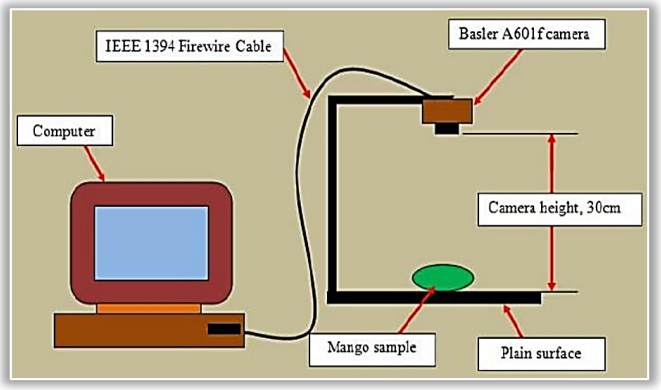

Figure 1: Elements of machine vision system by Bio-inspired Vision Fusion for Quality Assessment of Mango

TERMINAL VELOCITY AND DRAG COEFFICIENT IN POSTHARVEST PROCESSING

Understanding the aerodynamic properties of agricultural produce such as the terminal velocity and drag coefficient, is important for the design of structures and equipment used in operations such as pneumatic and hydraulic transportation of agricultural products; grains classification and cleaning, grain spreading equipment used in storage bins and grain drying (Binelo et al., 2019a). The terminal velocity and drag coefficient of different seeds and other food products have been studied by different authors. Terminal velocity has previously been determined as a function of moisture content from a number of aerodynamic tests with different agricultural products. However, some studies showed that terminal velocity of an agricultural products also changes according to the mass, form, volume and superficial area of the product (McGinley and Brigham, 1989). As reported by Mirzaee *et al*. (2008), noted that the interaction between several particles in airflow causes a significant reduction in terminal velocity, when compared to that of a single particle. Mohsenin (2020) mention that another factor influencing the determination of the terminal velocity is the intensity of turbulence of the air flow. A decrease in the terminal velocity and an increase in the drag coefficients of cotton were recorded with increasing airflow turbulence intensity. Gürsoy and Güzel (2010), studied the physical and aerodynamic properties of wheat, barley, chickpeas and lentil seeds. They performed experiments and use mathematical models to define the terminal velocity and the drag coefficient of each seed type. Although the complete modelling of airflows around the seeds can offer more detailed and realistic results, its implementation, considering a system with movement and interaction among many seeds, becomes impracticable. As an alternative, if the drag force coefficient of a seed is known, it is possible to incorporate the effect of a simple air stream into the seed flow simulation, thereby providing a considerable improvement in the accuracy of the models a relatively low computational cost. The drag force coefficient can be obtained by obtaining the terminal velocity. There are two main methods to measure the terminal velocity, the free fall method and the fluidized bed method. The free fall

method is not very practical, since it requires the grain to fall from a high height, requiring precise equipment to measure the seed fall speed and fall time. the fluidized bed method is more practical. In this method, the seed is subjected to an ascending air stream, which is gradually increased until the grain starts to be suspended. The velocity of the air stream necessary to suspend the seed is equal to the seed terminal velocity (Mohsenin, 1986).

Drag is a hydrodynamic force acting opposite to the movement of a body through a fluid. Drag force is generated by the interaction of the body surface and the fluid medium both at different velocities and can be expressed as:

$$F_d = \frac{1}{2} C_d \rho_f A V^2 \quad (1)$$

where F_d is the drag force, C_d is the drag coefficient, ρ_f is the fluid density, A is the projected area perpendicular to the movement vector, and V is the relative velocity between the body and the fluid.

A body freely falling through a fluid will accelerate under the influence of gravity but since drag is proportional to the square of velocity, it will limit the fall velocity until it becomes constant at the so-called terminal velocity.

A body reaches its terminal velocity when the drag force becomes equal to its weight

$$F_d = mg \quad (2)$$

where m is the mass of the body and g is acceleration due to gravity. By substituting equation 2 in 1

$$mg = \frac{1}{2} C_d \rho_f A V^2 \quad (3)$$

Rearranging, the terminal velocity is defined as

$$V_\infty = \sqrt{\frac{2mg}{\rho_f C_d A}} \quad (4)$$

Furthermore, if the terminal velocity of the body is known the drag coefficient C_d can be derived by

$$C_d = \frac{2mg}{\rho_f A V_\infty^2} \quad (5)$$

— Seed Orientation and Projected Area

The project area A is a parameter that depends on the body shape and its orientation. Seeds have irregular shapes, making them difficult to accurately represent it in a simple mathematical model

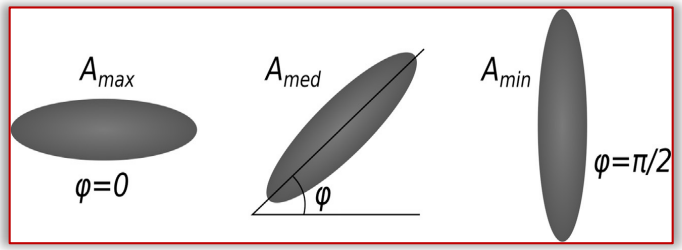

Figure 2: Seed orientation and projected area.
Source: Binelo *et al.* (2019).

Khatchatourian and Padilha (2008) developed algorithm that is used to detect the contours of each seeds, the contours are then processed and each seed is identified, as seen in Figure 3.

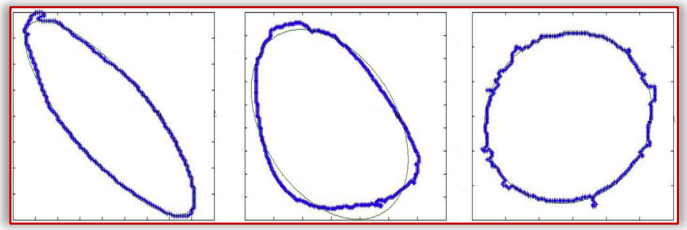

Figure 3: Eclipse approximation

Gürsoy and Güzel (2010) studied the physical and aerodynamic properties of wheat, barley, chickpeas and lentil seeds. Experiments was performed and mathematical models to define the terminal velocity and the drag coefficient of each type of seed. To theoretically define the terminal velocity, equations, with a correction factor based on the form of each seed, were used. To obtain the drag coefficient, variations of grain orientation, and the consequent change in projection area relative to the fluid flow were considered. The average experimental terminal velocity was found to be in the range of 7.52 to 8.14 m/s for wheat varieties, 7.04 to 7.07 m /s for barley varieties, 7.72 to 7.78 m/s for lentil varieties and 11.15 to 12.01 m/s for chickpea varieties. The drag coefficients of seeds according to projected areas in different positions and equivalent spheres were calculated. The drag coefficient in the position of the lowest projected area for all the grain varieties was higher than that in the other position.

Ghamari *et al.* (2011) conducted fluidized bed experiments in order to determine the terminal velocity of chickpeas, rice and lentil seeds. The obtained results showed that terminal velocity for chickpeas ranged from 11.5 m/s to 15.08 m/s, rice terminal velocity ranged from 4.24 m/s to 5.01 m/s, and lentil terminal velocity ranged from 5.08 m/s to 6.41 m/s, according moisture content levels.

The terminal velocity is affected by the density, shape, size and moisture content of samples. Therefore, it is necessary to determine the aerodynamic properties as a function of different factors such as moisture content. Many valuable research works have been carried out about the aerodynamic properties of agro-food materials such as pistachio nut and its kernel (Razavi *et al.*, 2007). Figure 4 shows some pistachio nuts and kernels.

Figure. 4: Pistachio nuts and kernels.
Source: Kashaninejad *et al.* (2006).

Kashaninejad *et al.* (2006) determine some physical and aerodynamic properties of pistachio nuts and its kernel in order to design processing equipment and facilities. Several experiments were performed to investigate the moisture-dependent of aerodynamic and physical properties of pistachio nut and its kernel. Physical properties such as dimensions, sphericity, splitting, unit mass, bulk density, true density, porosity, static friction coefficient on various surfaces and terminal velocity were determined. The range of moisture content was selected from 4.10 % to 38.1 % (w.b). Terminal velocity increased from 6.45 to 7.32 m/s and the coefficient of static friction increased linearly against all the tested surfaces as the moisture content increased.

— Aerodynamic Properties of Coffee Beans

Knowledge of the aerodynamic properties of coffee cherries and beans is fundamental to the designing of the machines used in coffee production (harvesting, sorting, cleaning, drying, storage, processing and classification of the product) (Binelo et al., 2019b; Júnior *et al*., 2007). Most of the equipment uses either air or water to transport or separate the desirable and high quality product from either the impurities or lower quality materials. This knowledge may also be used in the improvement of those operations related to the handling and different processing stages of the material.

— Computation Fluid Dynamics for Modelling Terminal Velocity of Agricultural Granular Materials

Computational fluid dynamics uses powerful computers and applied mathematics to model fluidflow situations (Xia & Sun, 2002). The yardstick of success is how well the result of numerical simulation agree with experiment in cases where careful laboratory experiments can be established, and how well the simulations can predict highly complex phenomena that cannot be isolated in the laboratory.

Computational fluid dynamics has received extensive attention throughout the international community since the advent of the digital computer. Since the late 1960s, there has been considerable growth in the development and application of computational fluid dynamics. However, it is only in recent years that computational fluid dynamics has been applied in food processing (Scott, 1992). Computational fluid dynamics as a tool of research for enhancing the design process and understanding of the basic physical nature of fluid dynamics, can provide benefits to the food processing industry in many areas, such as drying, sterilization, mixing, refrigeration and other applicable areas. In the past few years' great development has taken place in these areas (Scott, 1992).

— Aerodynamics property in Drying of Agricultural Produce Using Computational Fluid Dynamics

The drying rate is a strong function of air flow or air velocity. Therefore, it is of great importance to know the airflow and velocity in the drying chamber, thus leading to know the areas of adequate air velocities for proper drying. However, air flow and air velocity are difficult to measure during operation because several sensors are needed to be placed at various directions of air flow and locations. Since there are some difficulties in modelling the complex phenomena, especially the gas turbulence. Computational fluid dynamics is a powerful tool to aid the prediction of drying process. Computational fluid dynamics has been used to predict the air flow and velocity during drying. Mathioulakis *et al.* (1998) used computational fluid dynamics to simulate the air movement inside an industrial batch-type tray air drier. Dry test of several fruits were performed and the results showed that the degree of fruits dryness depended on its position within the drier. Determination of pressure profiles and air velocity by computational fluid dynamics showed that the main cause of the variations in drying rates and moisture contents was lack of spatial homogeneity of air velocity within the drier. Mirade (2003) studied velocity fields in a modern sausage drier in order to provide the information on air circulation inside the drier, which showed that computational fluid dynamics was able to predict the effects of filling level on air flow patterns and also to identify measurement errors in areas where the main air flow direction was horizontal.

Computation fluid dynamics has also been use to investigate the performance and the design of spray dryers in the food industry. Spray dryers are used to produce products such as milk and coffee powder, as well as detergents. However, the design of spray dryers for the food industry is difficult because the performance of spray dryers is heavily influenced by the complexity of air and spray flow patterns inside the dryers.

— Measuring Aerodynamic Properties of Agricultural Products

Two commonly used methods of measuring the terminal velocity experimentally are the suspension and drag methods. The suspension method allows a particle to be suspended in a vertical duct by blowing air in a duct and measuring the air speed at a moment when the particles is suspended. Under these conditions the weight of the particle becomes equal to the drag force (Gharekhani *et al*., 2013; Mohsenin, 1986). The drop method involves dropping the particle from a certain height whereby the particles will reach their terminal velocity after dropping a certain distance. Terminal velocity can be taken from the distance versus time curve where it begins to become linear. The advantage of the drop test for particles with lower terminal velocities is that it is less difficult to use than the suspension method (Gorial and O'callaghan, 1990; Gupta *et al*., 2007; Gürsoy and Güzel, 2010; Razavi *et al*., 2007).

CONCLUSION

Review of the terminal velocities and drag coefficients revealed the following: increase in moisture content and true density affect the aerodynamic properties of the product leading to increase in terminal velocity and a reduction in drag coefficients for different agricultural products. One of the impressive factors of optimizing the

harvesting of cereals is terminal velocity and its variation regarding the ambient conditions. Computational fluid dynamics is a validated method that can simulate the phenomenon and help with a prediction of some characteristics. The result can be basis for simulating the transfer of granular material in food processing devices. Biological materials that are consumed as food or feed undergo various unit operations right from the harvesting and postharvest processing. Designing and selecting tools as well as equipment's requires knowledge of the hydro and aerodynamic properties of agricultural materials. Undesirable materials such as light grains, weeds seeds, chaff, plant leaves and stalks can be removed with air flow when grains, fruits and vegetables are mechanically harvested. In addition, agricultural materials are routinely conveyed using air stream in pneumatic conveyors. If these systems are not used properly, they could cause problems.

For example, in a combine harvester, if the air speed is low, the materials would not be separated from each other and there will be extra foreign material with the product. If air speed is high the product will be exhausted along with extra materials and product loss will increase. For conveying agricultural material, the range of proper air streams should be used. With low air speed, there is stagnation in the system, or with high air speed, there will not only be energy lost but also grains may be broken.

The proper air speed can be determined from aerodynamic properties of agricultural materials. These properties are terminal velocity and drag coefficient. Knowledge of aerodynamic properties in agricultural products is of vital importance. In order to design efficient equipment for the harvesting and post-harvesting of agricultural materials, it is necessary to know its aerodynamic behaviour. Knowledge of hydro and aerodynamic properties of agricultural foods and products are important for designing the equipment for processing, transportation, sorting, separation and storing. Designing such equipment without taking these into consideration may yield poor results. The major moisture-dependent physical properties of biological materials are shape, size, mass, bulk density, true density and porosity. Aerodynamic properties such as the terminal velocity of agricultural products are important and required for the design of air conveying systems and the separation equipment. Physical properties such as density, shape, and size, need to be known for calculating the terminal velocity and drag coefficient for separating the desirable products from unwanted materials. Aerodynamic properties such as terminal velocity and drag coefficient are needed for air conveying and pneumatic separation of materials (Gupta *et al*., 2007). The two commonly used methods of measuring terminal velocity experimentally are the suspension and drag methods.

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[1.]Arinola Bola AJAYI, [1.]Olumide Edward ABEGUNDE

DEVELOPMENT OF A RENEWABLE ENERGY BARBECUE GRILLING MACHINE

[1.] Department of Mechanical Engineering, Faculty of Engineering, University of Lagos, Akoka, Yaba, Lagos, NIGERIA

Abstract: This paper presents the development of a renewable energy barbecue grill. The grill produces the heating effect required for grilling meat/fish by using a clean and renewable energy source (solar energy) for the electricity supplied. The portable grill was developed to replace fossil fuel burning grills. Burning of fossil fuel is usually associated with high energy cost, emission of greenhouse gases and choking effect felt by the grill operator as a result of smoke inhalation from the grill. The renewable energy barbecue grill is made with 12 volts dc heating element, a temperature sensor, an Arduino Uno module, 30 A, 12/24 V solar charge controller, 120 AH 12 V battery and two 160 W solar panel modules. Analysis and sizing of the grilling machine heating element, battery and the solar panel are presented in this paper. Solar energy incidents on the solar panel which produces direct current that flows from the Solar PV panels through the wiring systems into the battery through a charge controller. The charge controller prevents over charging/discharging of the battery and also prevents current in the battery from flowing back to the solar panel at night or when there is no charging from the Solar Panels. The current then flows into the heating element from the battery through connecting wires and it generates the heat required for grilling of the food item. An experiment was performed to observe the grilling of the food item. It was observed that the grilling operation was carried out in about fifty minutes which makes this device to be highly efficient. It is concluded that this device can replace the conventional fossil fuel barbecue grills especially in regions of high solar insolation
Keywords: Arduino Uno, Barbecue, Heating Element, Grilling, Renewable Energy, Solar PV Panel

INTRODUCTION

Grilling involves applying significant amount of direct and radiant heat to the surface of the food in order to roast it. The device that is used for grilling is called a grill or a grill pan. Grilling is a type of cooking method that has existed in many parts of the world in the pre-colonial era. For over 500,000 years, mankind has been making use of fire to roast food. The early men roasted their meat on a wooden structure before consumption (Green, 2012). Direct heat grilling can subject the food to a temperature mostly above 250**℃**. Grilled meats also acquire a distinctive aroma because of chemical reaction known as maillard reaction in which the amino acids and sugars react together in the presence of heat (Schroder, 2003). Foods are grilled for their numerous advantages which include less fat than the conventionally cooked food which retains the fat which could be health hazard upon consumption. Also, the grilled food retains nutrient according to Wiggins, 2018 unlike being washed away in cooking. However, grilling has its own disadvantages as well. It can be affected by rain and dust if exposed. Also, cooking beef and some other food at very high temperatures can lead to formation of heterocyclic amines and some other compounds which are carcinogens (Williams, 2019). Various methods of grilling include the grid ironing which involves grilling of food using grill suspended above the heat surface; Charcoal kettle-grilling which uses charcoal fire as the source of heat; solar grilling; gas powered grills and so on. Renewable energy is energy that is obtained from renewable sources that can be replenished constantly. Examples of renewable energy sources are sunlight, wind, rain, tides, waves and geothermal. These sources can be harnessed and used in some engineering sectors such as electricity generation, cooling and heating of air and water, off-grid and transportation energy services (Sawin & Martinot, 2010). The use of renewable energy started about a million years ago before the development of coal in the 19th century. In those days, biomass was used to fuel fires, wind was harnessed to drive ships over water, etc. In 2017, renewable energy contributed 19.3% to human global energy consumption and 24.5% to the generation of electricity (United Nations, 2018). Lately, solar energy has been used more because of the recent increase in the cost of energy (Lynch, 2008). Photovoltaic cells were used to convert solar energy into electrical energy which is then used to power many electrical appliances. The type of current produced from the solar panel (photovoltaic cell) is a direct current and most appliances operate on alternating currents hence an inverter can be used to convert the current from DC to AC (Dave, 2019). A renewable powered barbecue grill is a device that harnesses solar energy to grill food. There are few methods in which this can be done. One method includes using solar collector and reflectors to focus beams of light on the focal point where the food to be grilled must have been positioned. This is a direct use of sunlight to grill. Another method is to use photovoltaic cells to power heating coils over the range of high temperature, the heating coils then radiate heat unto the food to be cooked which is an indirect use of sunlight. Advantage of the solar powered barbecue grill is that it integrates clean energy and reduce pollution that can be caused by coal fired grills, it is cheap, efficient and easy to use in the rural areas where other forms of energies especially grid lines are not readily available. Various grilling machines have been created in the past. They include the Gas grill, Charcoal grill, electric grills. The gas grilling machine is usually associated with high running cost in terms of energy source cost, high energy cost is associated with high running cost which could mean reduced profit for a businessman. According to

Harris (1999), the flavor is not as good as that of the charcoal due to the chemical composition of the gas, they also dry out the food which makes it tough as a result of the direct exposure of the food to extended application of flames. Also, when the piece of food falls on the fire from burner, flare-ups occur. These flare-ups are major source of fire accident and can be fatal, it can also cause overcooking of food or burning of food, hence there is need for constant monitoring of the grilling process. The smoke caused by the flare-ups also create harmful emissions and also make the food carcinogenic. (World Health Organization, 2015). The charcoal grill takes a long time before proper grilling, the temperature is harder to control, the ash is hard to deal with which makes it takes longer time to clean. and the costs of charcoal is high and it burns rapidly (Slater 2016). Burning of charcoal causes air pollution and causes emissions of some gases like CO_2 which are not environmentally friendly (Chafe, et al., 2016). Also, when oil from the food drops on the fire, flare - ups occur which have the same effects as that in gas grilling machine accidents can occur (World Health Organization, 2015). Electric grills mostly use ac electric current which can shock the operator and they consume very high amount of energy. Giguere & Thibodeau (1974) discovered that the electric heater generates too much heat when used indoor and they can cause fire accident when they come in contact with combustible materials. The aim of this paper is to present the development of a renewable energy barbecue grilling machine for grilling food items. The objectives of this paper include the design of a renewable energy powered barbecue grill and fabrication of the solar powered barbecue grill and testing of the barbecue grilling machine. The importance of this study includes: (1) It helps to reduce air pollution that can be caused by the use of fossil fuel fire, (2) It also reduces the financial cost of energy because the sunlight is available at a cheaper cost and (3) It helps to eliminate dangers of electric shock, flare ups and (4) It helps to eliminate dangers of toxic smokes during use.

MATERIALS AND METHODS

The materials and methodology for the design and development of Renewable Energy Grilling Machine (REGM) are discussed below. Although, the REGM is going to be used at Abule Okuta (Bariga) Bus Stop, Lagos, it can be deployed in any area as long as there will be daily sunshine. It is intended to replace gas fired grilling machine already in use there.

— Design Analysis and Consideration

Various factors were considered in order to develop an efficient solar PV powered barbecue grilling machine. The considerations are: heat energy required to grill food items, the temperature of the air at the point of contact with the food, the size of Solar PV panels required to provide the required power and the battery storage capacity to store and release the power when needed. The thermal conductivity of the materials to be used.

— Heat energy required for grilling

The food to be grilled is model as a homogeneous wall that is conductive and being heated on one side while other side is in free air as shown in Figure 1 below. Newton's law of cooling states that the heat transfer from a solid surface of area, A, at a temperature t_w, to a fluid of temperature t, is given by equation (1) below in (1)

$$Q = hA(t_w - t) \quad (1)$$

where Q = heat transfer (W), h = heat transfer coefficient (W/m^2. K) and it depends on the properties of the fluid and the fluid velocity. t_w = temperature of the wall and t = temperature of the free space.

According to Fourier's law of conduction, the rate of flow of heat through a single homogenous solid is directly proportional to the area, A, of the section at right angles to the direction of heat flow, and to the change of temperature with respect to the length of the path of the flow $\frac{dT}{dx}$. The thermal resistance concepts is given in the heat conduction through a solid and it is given in equation (2) below

$$Q = \frac{T_1 - T_2}{R_{solid}} \quad (2)$$

where Rsolid = thermal resistance of the solid (k/W)

The various expressions for Rs are given in equation (3a) and equation (3b) below

$$R(solid) = \frac{L}{KA} \quad (3a)$$

$$R(conv) = \frac{1}{hA} \quad (3b)$$

Consider a steady state one-dimensional heat flow through a plane wall of thickness x, area A, and thermal conductivity k that is exposed to heat convection on both sides at temperatures $T_{(\infty 1)}$ and $T_{(\infty 2)}$ with heat transfer coefficients h_1 and h_2 respectively, as shown in Figure 1 below. Assuming $T_{(\infty 2)} < T_{(\infty 1)}$, the variation of temperature will be as shown in Figure 1 below. Note that the temperature is assumed to vary linearly in the wall (the material to be grilled food since we assumed an homogeneous material), and asymptotically approaches $T_{(\infty 1)}$ and $T_{(\infty 2)}$ in the fluids as we move away from the wall.

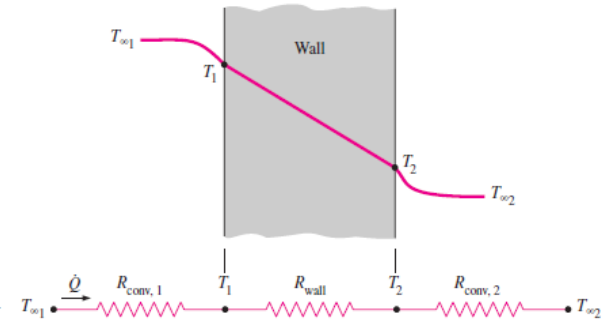

Figure 1: Conductive wall and Electrical resistance models of the Grilled materials

In a steady state heat flow, the rate of heat convection into the fish (wall) = rate of heat conduction through the fish (wall) = rate of heat convection from the fish (wall).

Therefore,

$$Q = h_1A[T_{(\infty,1)} - T_{(\infty,2)}] = h_2A[T_{(1)} - T_{(\infty,2)}] = kA\frac{T_1 - T_2}{x} \quad (4a)$$

$$Q = \frac{[T_{(\infty,1)} - T_{(1)}]}{h_1 A} = \frac{[T_{(1)} - T_{(\infty,2)}]}{h_2 A} = \frac{T_1 - T_2}{x/kA} \quad (4b)$$

Adding up the numerators, we get

$$T_{(\infty,1)} - T_{(\infty,2)} = Q\left[\frac{1}{h_1} + \frac{1}{h_2} + \frac{L}{kA}\right] \quad (5)$$

Therefore,

$$R(total) = \left[\frac{1}{h_1} + \frac{1}{h_2} + \frac{x}{kA}\right] \quad (6)$$

$$Q = \frac{T_{(\infty,1)} - T_{(\infty,2)}}{\left[\frac{1}{h_1} + \frac{1}{h_2} + \frac{L}{kA}\right]} \quad (7)$$

To determine the heat energy required to grill a mass of food item, the relationship shown in equation (8) below is employed:

$$Q = m \times C_P \times \Delta T \quad (8)$$

where Q = heat energy required (J), m = mass of food item (kg), C_P = specific heat capacity (KJ/Kg℃) and ΔT = temperature change (℃)

It is assumed that the food to be grilled; fish, meat and chicken were defrosted already at 20°C and will be heated to 250°C for it to be properly grilled. The specific heat capacities for fish (fresh Crocker), beef and chicken are 3.6 KJ/Kg℃, 2.85 KJ/Kg℃, 3.1 KJ/Kg℃ respectively (The Engineering Toolbox, 2003). Therefore, the heat required to grill the fish, beef and chicken are given below in equations (9a), (9b), and (9c) respectively

For fish, $q = 0.5 \times 3.6 \times (250 - 20) = 414kJ$ (9a)

For beef, $q = 0.5 \times 2.85 \times (250 - 20) = 327.75kJ$ (9b)

For chicken, $q = 0.5 \times 3.1 \times (250 - 20) = 356.5kJ$ (9c)

The power required is given by the expression in equation (10) below:

$$\text{The power required} = \frac{\text{heat energy required}}{\text{total time required}}. \quad (10)$$

The power required to grill the fish, beef and chicken are given below in equations (11a), (11b), and (11c) respectively

$$\text{For fish, power} = \frac{414000}{1800} = 230 \text{ watts} \quad (11a)$$

$$\text{For beef, power} = \frac{327750}{1800} = 182 \text{ watts} \quad (11b)$$

$$\text{For chicken, power} = \frac{356500}{1800} = 198 \text{ watts} \quad (11c)$$

The heating energy, E, in the heating element is given by the expression in equation (12),

$$E = I^2 \times R \times t \quad (12)$$

where I = current that flows through the heating element, R = resistance of the heating element, t = time,

Power of the heating element, P = 250 W. The margin of safety of 20 percent assumed will give: 250 W x 1.2 = 300 W. Voltage of the heating element, V = 12 V

$$I = \frac{300}{12} = 25 \text{ A} \quad (13)$$

Also, the resistance of the coil is obtained from:

$$P = \frac{V^2}{R} \quad (14)$$

R= 0.48 ohms

The grilling machine will be operated between the hour of 1800 hours and 2300 hours. Therefore, the total energy requirement is = 300 W x 5 hours = 1, 500 Wh/day = 1.5 kWh/day.

— Temperature of the air at the point of contact with the food

The grilling machine is modelled as two materials in series with an air gap between them as shown in Figure 2 and the heat source from the heating element. We can now determine the temperature of the air that grills the food item.

Given:

Thermal conductivity of fish = 0.534 W/m K, Thermal conductivity of chicken = 0.503 W/m K, Thermal conductivity of beef = 0.506 W/m K, Initial temperature of food = 20 ℃, Temperature of the air = 25 ℃, thickness of food to be grilled = 0.02 m. temperature of the grill = 500 ℃, the length of the airgap is = 0.06 m

Assumptions made:

- R (air gap) = 0.16 k/W
- area = 1 m^2
- thickness of food to be grilled = 0.02 m
- the heat transfer coefficient of the outside air=17 W/m^2 K
- heat transfer through the wall is steady since the surface temperatures remain constant at the specified values
- thermal conductivity is constant
- heat energy is considered to flow at a uniform rate
- heat transfer by radiation is negligible
- area of the solid is constant
- assume Newton's law of cooling for heat transfer at the fluid and solid interface

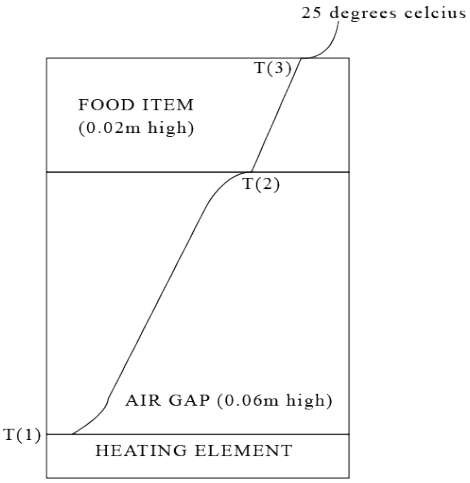

Figure 2: Schematics of the heat transfer from the heating element to the food item

At T_1 = 500℃, and T_{air} = 25℃,

$$Q = \frac{T_1 - T_{air\ outside}}{R_{Total}}$$

$$R_{(Total)} = R_{(air\ gap)} + R_{(fish)} + R_{(air\ outside)}$$

$$R_{(fish)} = \frac{L}{K*A} = 0.037 \text{ k/W}$$

$$R_{(outside)} = \frac{1}{h*A} = 0.057 \text{ k/W}$$

$$R_{(Total)} = 0.16 + 0.037 + 0.059 = 0.256 \text{ k/W}$$

$$Q = \frac{500 - 25}{0.256} = 1855.4 \text{ W}$$

Since the setup is in series, the same heat energy flows through them

To obtain the temperature at the interface of the air gap and the fish, $T_{(2)}$:

$$\frac{500-T_2}{0.16} = 1855.4\ W$$

$$T_{(2)} = 205℃$$

To obtain the temperature at the interface of the fish and the surrounding air, $T_{(3)}$:

$$\frac{205-T_{(3)}}{0.037} = 1855.4\ W$$

$$T_{(3)} = 136.4℃$$

— Solar PV panel

A solar PV panel as shown in Figure 3 is a device that is made up of many photovoltaic cells linked up together. A photovoltaic cell is a cell that mainly converts sunlight into electricity. When photons incident upon an atom, an electron is released from the outer shell of the atom. This flow of electron generates a flow of electricity. This device is the only source of energy in this work. It supplies DC current to the heating element through the charge controller and battery. It is usually tilted at an angle from the ground to improve the efficiency. The tilting depends on the latitude of the location which is 3.3^0. The power generated by one solar power depends on many factors which are related by Eq. 16

$$P_{PV} = R_{PV} \times D_{PV} \times \left(\frac{S_i}{I_{sc}}\right) \quad (15)$$

Where R_{PV} = Rated power capacity of the needed PV, D_{PV} = Derating of the PV (%), S_i = Global solar irradiation (kW/m^2), I_{SC} = Incident amount of solar irradiation at standard condition. The derating factor accounts for the solar PV panel power losses which can be due to dust cover on the surfaces of the panels and elevated temperature during exposure. Derating factor (D_{PV}) is taken to be 0.9 as reported in F. Rinaldi et. al (2020)

Figure 3: Solar PV panels exposed to the sunlight

— Sizing of the solar panel

Solar PV panels sizing always depend on the load and average daily sun hours in the locality. The power generation rating of a solar panel is watts. In reality, the energy generated by solar PV panels is obtained by multiplying solar capacity by average daily sunlight. This is what will be supplied to the battery for storage. The grilling machine will be deployed at Bariga Market (6.537406, 3.391975) Lagos. According to NREL, the average daily solar radiation in this area is 5.12 kWh/m^2/day (NREL, 2021)

The load required is = 1, 500 Wh = 1.5 kWh/day

The solar power requirement is 1.5 kWh ÷ 5.12 kWh/m^2/day = 0.293 m^2 at standard condition of 1000W/m^2 and T_c of 25°C

The wattage of the solar panel = 0.293 m^2 x 1000 W/m^2 = 293 W

Two 160 W Monocrystalline solar panels with the following specification: Peak power (PMP) – 160 Wp, Open circuit voltage of 21.84 V and Maximum Power Current (IMP) 8.80 A, Maximum Power Voltage 18.20 V, Short Circuit current of 9.33 A were selected and connected in parallel giving maximum power voltage of 18.20 V output and maximum short circuit current of 18.66 A. Photovoltaic rated at 1000 W/m^2, solar irradiation AM = 1.5 at 25^0C cell temperature.

— Charge Controller

This is a device that controls the amount of energy that is supplied to and drawn from the battery. The charge controller, shown in Figure 4, is placed between the solar panel and the battery. The solar charge controller controls the way the battery works that is charging and discharging operations. It also prevents the battery from overcharging thereby extending the service life of the battery. Overcharging the battery will reduce its service life. The charge controller stops the battery from discharging through the solar panel when there is no insolation especially at night. The charge controller has six terminals, two for the solar PV panels, two for the battery connections and the remaining two for the load hook up.

— Sizing of the charge controller

The maximum current that flows through the charge controller system is 18.66 A

The solar charge controller rating = Total short circuit current rating of PV array × 1.3 = 18.66 × 1.3 = 24.23 A.

Therefore, a 25 A charge controller is selected.

Figure 4: A Solar charge controller

— Battery

A battery is a device made up of one or more electrochemical cell and it is used to store electrical charges. A deep cycle battery, shown in Figure 5, which stores the charges from the Solar panel and supplies the charges to the heating element is used. The battery used for this experiment is of 12V, 120AH. An electric battery.

— Sizing of the battery

Since the system is designed to be used at sun down periods then, there must be deep cycle batteries to store up

the charges during the day so as to power the heating element for about 5 hours needed during off sunlight hours. The sizing of the battery would be done as follows:
Assuming 80% Depth of discharge for the battery
Power rating of the heating element and margin of safety, P = 300 watts and operating voltage, V = 12 V. But the energy generated by the two 160 W solar panels for 5.12 hours will be 1, 638 Wh

$$P = VI$$

≡ Part A:

The current drawn from the heating element, $I = \frac{250}{12} = 20.8A$

Battery capacity (AH) $= \frac{It}{0.8}$

Battery capacity (AH) $= \frac{20.8*5}{0.8} = 130$ AH

≡ Part B:

Energy to be stored = 1, 638 Wh
The battery is 12 V, : 1, 638 Wh ÷ 12 V = 136.5 Ah
Two 70 Ah, 12 V batteries selected which will give a combined capacity of 140 Ah at 12 V.

Figure 5: A sealed battery

— Heating element

Heating element, Figure 6, is a device that mainly converts electrical current into heat energy by the principle of joule heating. The heating element is made of resistance heating element, electrical insulator and metal casing. The material of the resistance heating element for this experiment is made of stainless steel in order to prevent contamination of the food item. This device is supported by the frame and it grills the food item directly above it. The heating element used in this project is 250 watt, 12 volts direct current.

Figure 6: Heating element

≡ **The Grill Mesh**: Figure 7 below is the picture of the grill mesh. It serves as a means of supporting the food items to be grilled. It is being supported by the frame and it rests above the heating element. It is made of stainless steel as well to prevent corrosion by the hydrated food.

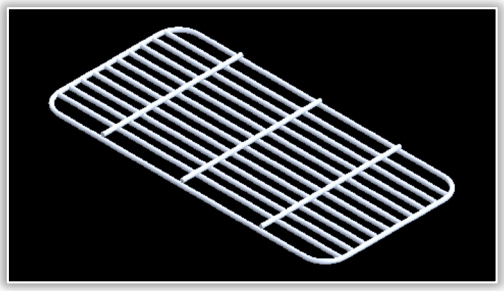

Figure 7: Grill Mesh

≡ **Temperature sensor:** The temperature sensor is shown in Figure 8 below. It is a MAX 6675 K-Type thermocouple temperature sensor. It performs cold-junction compensation and digitizes the signal from a type-K thermocouple. The data is output in a 12-bit resolution, SPI™-compatible, read-only format. MAX6675 converter resolves temperatures to 0.25°C, allows readings as high as +1024°C, and exhibits thermocouple accuracy of 8 LSBs for temperatures ranging from 0°C to +700°C. It is placed just above the heating element to take the instantaneous temperature reading in the grilling machine.

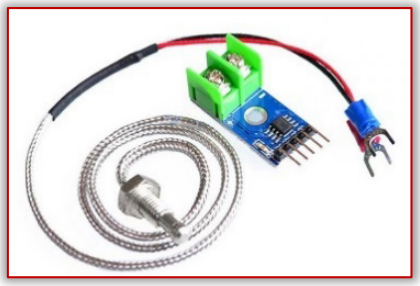

Figure 8: k-type thermocouple and Max 6675 temperature sensor

≡ **Connecting wires:** They are 4mm thick multi strnds wires used to connect the solar PV panels to the battery and the battery to the heating element.

≡ **Arduino Uno module:** Arduino Uno, Figure 9 below, is a microcontroller board that is equipped with sets of digital and analog inputs and output pins. The Arduino used for this experiment takes in the temperature and humidity readings from the sensors and displays it on the computer.

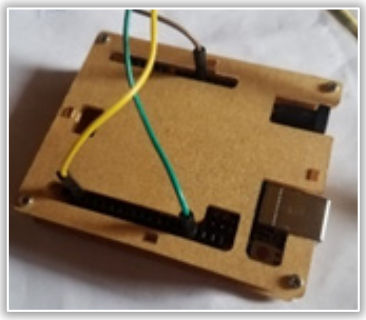

Figure 9: Arduino Uno module

≡ **Jumper wires**: They are used to connect the thermocouple sensor to the Arduino module.

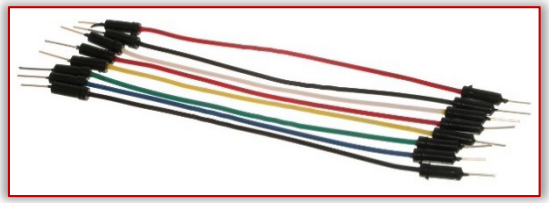

Figure 10: Jumper wires

≡ **The frame:** This serves as a housing support to the heating element. It has a passage for the drippings from the grilled meat and it also holds the switch and thermostat. It also serves as a support for the grill which is above the heating element.

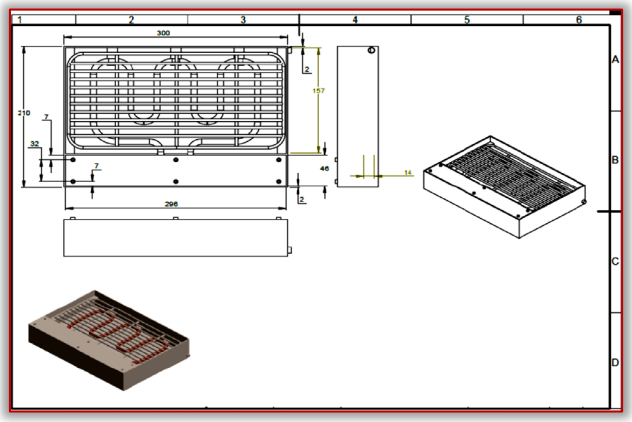

Figure 11: Assembly drawing of the solar grilling machine

≡ **Experimental setup:** The heating element was placed in the base frame and it is connected to the solar charge controller. The solar charge controller is connected to the battery and the solar panel. The experiment is set up as shown in Figures 12 and 13. Solar energy is the energy from the Sun, like other renewable energies, it is intermittent and not predictable. Hence, there is need for storage of energy generated so it can be used at a later time. The storage makes this energy more reliable. Various energy saving mechanisms exist. The most common one is the battery which saves electric current as charges. Therefore, the energy from the sun is converted to electric current using photovoltaic cells and stored in the battery for later use when there is no supply of energy from the Sun. The temperature and the humidity of the food item being grilled is measured using the K-type thermocouple and recorded, Table 1.

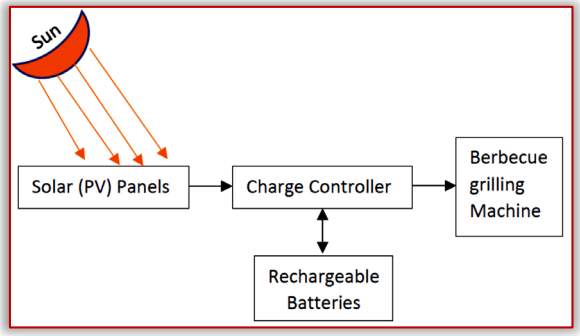

Figure 12: The Renewable Energy Grilling Machine set up

Figure 13: The experimental setup

Table 1: Temperature and relative humidity against time.

Time	Temperature (°C)	Relative humidity (%)
3.00pm	31.00	65.60
3.10pm	55.80	36.90
3.20pm	82.10	14.70
3.30pm	105.40	10.10
3.40pm	123.40	6.90
3.50pm	140.50	4.70
4.00pm	145.90	3.60

The solar panel converts the energy from the sunlight into electrical energy which flows through a Solar charge controller into a battery. The electrical energy leaves the battery through the same charge controller onto the heating element and it raises the temperature of the heating element. The food to be grilled is placed just above the heating element and it is grilled by natural convection. The grilling machine is covered with an insulating material in order to prevent heat losses.

After the construction of the solar powered barbecue grill, various tests of the components were carried out. The tests include the following:

✓ Determination of the time it takes to attain the various temperature ranges during the grilling operation.
✓ The temperature variation as time increases.
✓ The observation of the test specimen before and after the grilling process.

The experiment was carried out on an evening from 1500 hrs to 1600 hrs to test the performance of barbecue grilling machine.

Specimen = Fish
Weight before grilling = 0.5 kg.
Weight after grilling = 0.41 kg
Weight loss = 0.5 – 0.41 = 0.09 kg

Time taken for proper grilling = 50 minutes for both sides of the fish. Figures 14 and 15 are pictures of the fish before and after grilling respectively. The specimen was turned over manually.

Figure 14: Specimen before grilling

Figure 15: Specimen after grilling

RESULTS AND DISCUSSION

Figure 16 is the graph of temperature and humidity against time. The K-type thermocouple is placed on the furnace side of the fish. The fish (food) was covered to conserve the heat. From Figure 16, the temperature of the fish was rising as the humidity around the fish is reducing. The temperature and humidity began to rise and fall steadily after about 30 minutes.

The grilling actually started at about 20 minutes after the fish has been "de-watered". It is observed that the temperature increases for the first 40 minutes and then becomes steady as it approaches the maximum temperature of the heating element. The relative humidity first decreases sharply initially at the first 20 minutes and then becomes steady after 20 minutes.

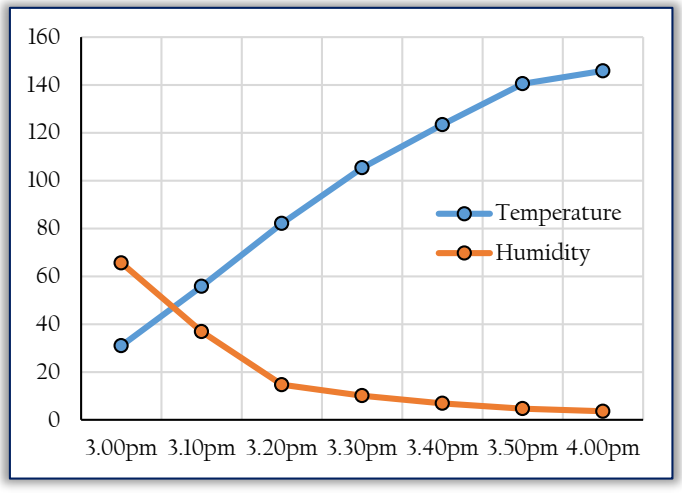

Figure 16: Graph of temperature and relative humidity against time

CONCLUSION

Renewable energy barbecue grilling machine was developed and tested in this article. It took about 50 – 60 minutes to grill 0.5 kg of fish. The machine could grill more food products especially fish, meat and chicken. It is important the top most part of the food is covered with noncombustible aluminum foil to conserve heat and get desired results as quickly as possible.

This project is able to eliminate flare-ups during grilling, reduce running cost, provides stable and evenly distributed flames that. It is fast when compared to the charcoal grilling machine. Since there is no burning of fossil fuels, and emissions, it is environmentally friendly and less harmful to human health. This project will therefore contribute to the reduction of carbon footprint in the environment where it is being operated.

This project is scalable and can be replicated anywhere whether in the rural areas or urban centers. The dwellers of rural areas can conserve the environment by saving the trees.

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[1.]Lan Hoang That TON

THREE KINDS OF POROSITY AND THEIR EFFECTS TO BENDING BEHAVIOR OF FUNCTIONALLY GRADED POROUS BEAMS BASED ON THE SIMPLE TIMOSHENKO BEAM THEORY

[1.]Dept. of Civil Engineering at HCMC University of Architecture, HCMC, VIETNAM

Abstract: In this paper, the effects of three types of porosity to bending behavior of functionally graded porous (FGP) beams are studied. The finite element procedure is established and based on the simple Timoshenko beam theory. The results achieved in this paper are presented and compared with other results in the references to verify the feasibility in implementing the formula and writing the Matlab code. On the other hand, this paper can help researchers to have an overview of the bending behavior of the functionally graded porous beams.

Keywords: Bending behavior, Functionally graded porous (FGP) beam, Transverse displacement, Rotation, Simple Timoshenko beam

INTRODUCTION

Nowadays, functionally graded (FG) material has become one of the smart materials and it is used in many countries. From a mixture of ceramic and metal, it provided the continuous variation of material properties from the top surface to the bottom surface of structure. For example, some structures like nuclear tanks, spacecraft, etc. are produced based on the above material [1-3]. Due to the high applicability of functionally graded material, many studies related to various theories have been given to comment the mechanical behavior of functionally graded structures as [4-9]. However, porosity of the material can occur during the manufacturing process [10-12]. So, for a good knowledge of porosity effect on bending behavior of functionally graded structures, a study related to this issue must be considered as soon as possible. There are three types of structure like beam, plate and shell, but researchers are usually interested in beam structures because of its wide applications. Furthermore, many different beam theories were used to analyze beam structures like simple beam theory [13], classical beam theory [14, 15], first-order shear deformation theory [16-20] or higher-order shear deformation theory [21, 22]. However, using a simple Timoshenko beam model helps us to reduce the computational cost with the resulting error within the allowable range. On the other hand, beams made of functionally graded porous materials should be investigated as much as possible to help the designer have right knowledge about the mechanical properties. The few published papers on static bending behavior of FG beams can be listed here. Author Chen and co-workers presented the Ritz method to obtain the transverse bending deflections and critical buckling loads, where the trial functions take the form of simple algebraic polynomials [23]. A novel model was introduced for bending of functionally graded porous cantilever beams by [24] related to shape memory alloy/poroelastic composite material. In this article, authors verified the accuracy of the bending model by three-dimensional finite element procedure. Another paper based on a trigonometric shear deformation theory was used to analyze the bending, vibration and buckling characteristics of functionally graded porous graphene-reinforced nanocomposite curved beams from [25], and so on. From above reasons, this paper is given to investigate the bending behavior of functionally graded porous beams.

This paper has four parts. Part 1 gives the introduction as above. Part 2 presents the formulations as well as Part 3 shows some essential results. Finally, a few comments are also given in Part 4 respectively.

FORMULATIONS

A FGP beam with length *L*, width *b* and thickness *h* is considered. Three forms of porosity distributions are studied and shown in Fig. 1, in which (*1*) is uniform porous distribution and (*2*) and (*3*) are non-uniform porous distributions respectively.

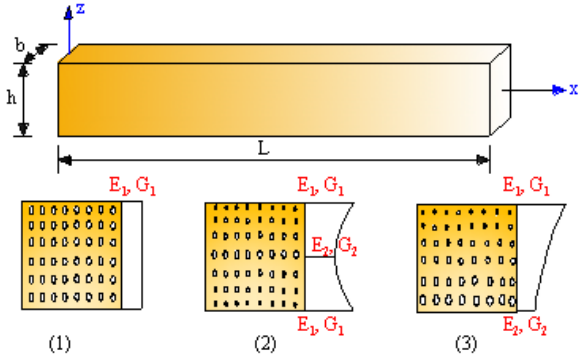

Figure 1. Functionally graded porous beam with three types of porosity 1, 2 & 3

The material properties *E(z)* and *G(z)* can be described as below

$$\begin{cases} E(z) = E_1(1 - e_0\chi) \\ G(z) = G_1(1 - e_0\chi) \end{cases} \quad \text{with} \quad (1)$$

$$\chi = \frac{1}{e_0} - \frac{1}{e_0}\left(\frac{2}{\pi}\sqrt{1-e_0} - \frac{2}{\pi} + 1\right)^2 \quad \text{for type (1)}$$

$$\begin{cases} E(z) = E_1\left(1 - e_0\cos\left(\frac{\pi z}{h}\right)\right) \\ G(z) = G_1\left(1 - e_0\cos\left(\frac{\pi z}{h}\right)\right) \end{cases} \quad \text{for type (2)} \quad (2)$$

$$\begin{cases} E(z) = E_1\left(1 - e_0 \cos\left(\dfrac{\pi z}{2h} + \dfrac{\pi}{4}\right)\right) \\ G(z) = G_1\left(1 - e_0 \cos\left(\dfrac{\pi z}{2h} + \dfrac{\pi}{4}\right)\right) \end{cases} \text{ for type (3)} \quad (3)$$

The porosity coefficient e_0 must satisfy $0 < e_0 < 1$ and

$$e_0 = 1 - \frac{E_2}{E_1} = 1 - \frac{G_2}{G_1} \quad (4)$$

Based on finite element method (FEM), the degrees of freedom associated with a node of a simple Timoshenko beam element are a transverse displacement and a rotation as depicted in Fig. 2. Using the principles of simple beam theory, the beam element stiffness matrix will be derived

$$K_e = \frac{E_e I_e}{L_e^3(1+\Phi)} \begin{bmatrix} 12 & 6L_e & -12 & 6L_e \\ 6L_e & (4+\Phi)L_e^2 & -6L_e & (2-\Phi)L_e^2 \\ -12 & -6L_e & 12 & -6L_e \\ 6L_e & (2-\Phi)L_e^2 & -6L_e & (4+\Phi)L_e^2 \end{bmatrix} \quad (5)$$

with

$$\Phi = \frac{12E_eI_e}{G_e k A_e L_e^2} \quad (6)$$

and k =5/6 is called the shear correct factor.

According to the principle of minimum total potential energy, the element equation can be described as

$$\frac{E_eI_e}{L_e^3(1+\Phi)} \begin{bmatrix} 12 & 6L_e & -12 & 6L_e \\ 6L_e & (4+\Phi)L_e^2 & -6L_e & (2-\Phi)L_e^2 \\ -12 & -6L_e & 12 & -6L_e \\ 6L_e & (2-\Phi)L_e^2 & -6L_e & (4+\Phi)L_e^2 \end{bmatrix} \begin{Bmatrix} w_i \\ \varphi_i \\ w_j \\ \varphi_j \end{Bmatrix} = \begin{Bmatrix} f_i \\ m_i \\ f_j \\ m_j \end{Bmatrix} \quad (7)$$

After assembly, the bending parameters can be obtained by solving the following equation

$$\mathbf{Kd} = \mathbf{F} \quad (8)$$

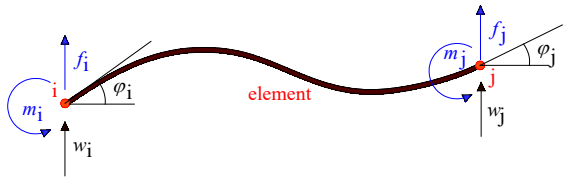

Figure 2. The simple Timoshenko beam element

By using three letters 'C', 'S' and 'F' refer to the clamped, simply supported and free condition, all boundary conditions can be revealed as below

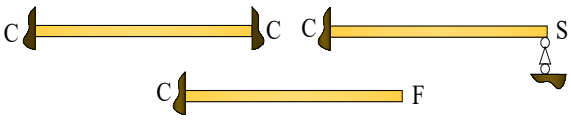

Figure 3. Three types of beam

$$\text{(CS)}\ w(0) = \varphi(0) = 0,\ w(L) = 0 \quad (9)$$

$$\text{(CC)}\ w(0) = \varphi(0) = 0,\ w(\mathrm{L}) = \varphi(\mathrm{L}) = 0 \quad (10)$$

$$\text{(CF)}\ w(0) = \varphi(0) = 0 \quad (11)$$

More clearly, the finite element system of equations can be reached as below:

- Input data: geometric data and material properties.
- Calculating constitutive matrix.
- Loop over elements: calculating element stiffness matrix and element force vector.
- Assembling all parts in the global coordinate system
- Applying boundary conditions
- Solving equation for static bending
- Display transverse displacements and rotations at nodes of system.

NUMERICAL EXAMPLES

Firstly, the validity of the proposed model is checked for (CC) and (CS) isotropic beams under a uniform load $q = 10^6$ N/m^2. The material and geometric properties are E = 1GPa, v = 1/3, b = 0.1m, h = 0.1m and $L = 10h$. The maximum transverse displacement and rotation as in Table 1 are calculated and compared with analytical solutions [26] as follows:

(CC)

$$w = \frac{1}{EI}\left[\frac{1}{24}qL^2x^2 - \frac{1}{12}qLx^3 + \frac{1}{24}qx^4\right] \quad (12)$$

$$\varphi = \frac{1}{EI}\left[\frac{1}{12}qL^2x - \frac{1}{4}qLx^2 + \frac{1}{6}qx^3\right] \quad (13)$$

(CS)

$$w = \frac{1}{48EI}\left[-3qL^2x^2 + 5qLx^3 - 2qx^4\right] \quad (14)$$

$$\varphi = \frac{1}{48EI}\left[-6qL^2x + 15qLx^2 - 8qx^3\right] \quad (15)$$

Table 1. The comparison of the maximum transverse displacements at position x = L/2 of (SS) isotropic beams with L/h = 5

	w_{max}		φ_{max}	
CC	Analytical	Paper	Analytical	Paper
	0.3125	0.3126	0.9375	0.9383
	w_{max}		φ_{max}	
CS	Analytical	Paper	Analytical	Paper
	0.6480	0.6466	1.7187	1.7002

It can be seen that the results obtained from the paper are completely approximate with other results. The relative error among above results can be explained by using different approaches.

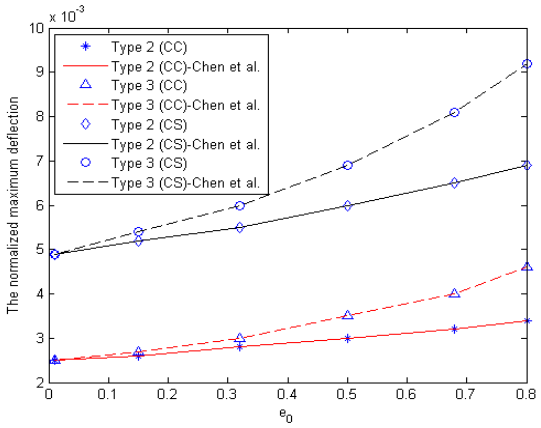

Figure 4. Convergence of the deflection

Secondly, the material of the porous beam is assumed to be steel foam with E_0 = 200 GPa, v = 1/3. The cross section of beam is h = 0.1m, b = 0.1m . The normalized maximum deflections $\overline{w} = w_{max}/h$ based on this study for two boundary conditions (CC) and (CS) are compared with other results of [23] as in Figure 4. Again, their convergence proves the reliability of the proposed method in bending analysis of functionally graded porous beams.

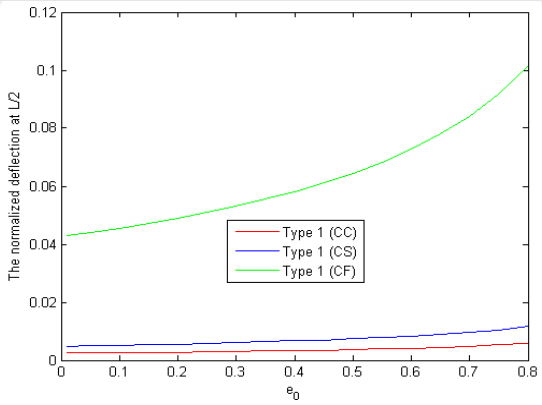

Figure 5. The influence of e_0 on the deflection of porous beam with type 1 for three boundary conditions

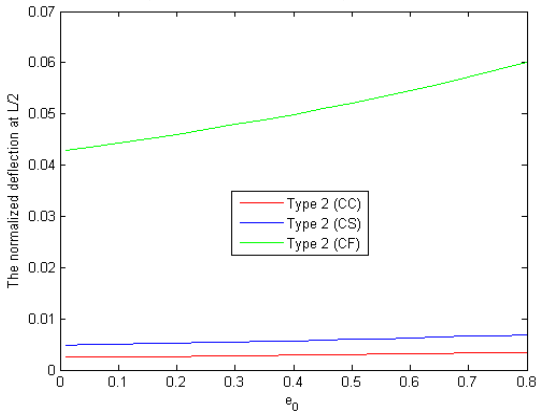

Figure 6. The influence of e_0 on the deflection of porous beam with type 2 for three boundary conditions

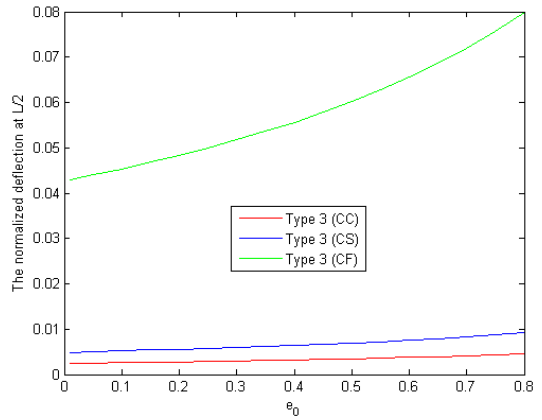

Figure 7. The influence of e_0 on the deflection of porous beam with type 3 for three boundary conditions

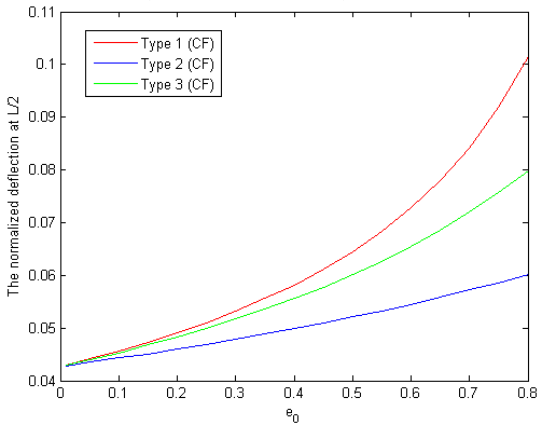

Figure 8. The influence of e_0 on the deflection of (CF) porous beam with three types 1, 2 & 3

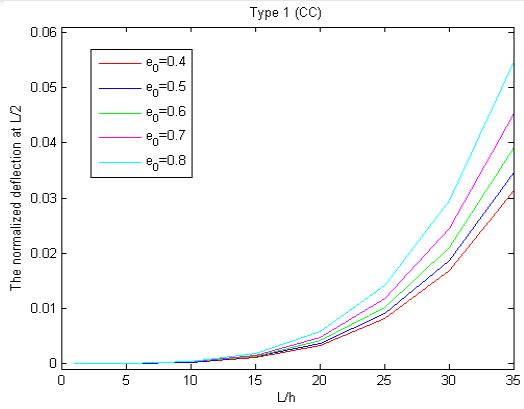

Figure 9. The deflections of type 1 (CC) porous beam by changing ratio L/h and porosity factor e_0

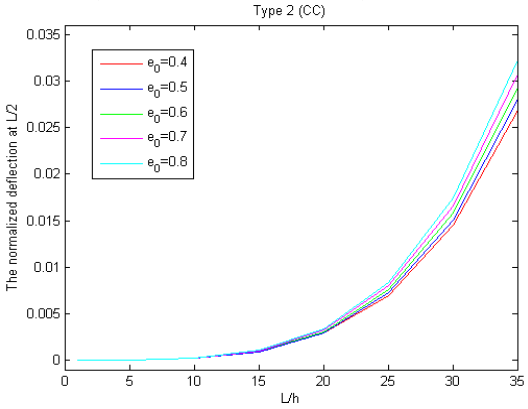

Figure 10. The deflections of type 2 (CC) porous beam by changing ratio L/h and porosity factor e_0

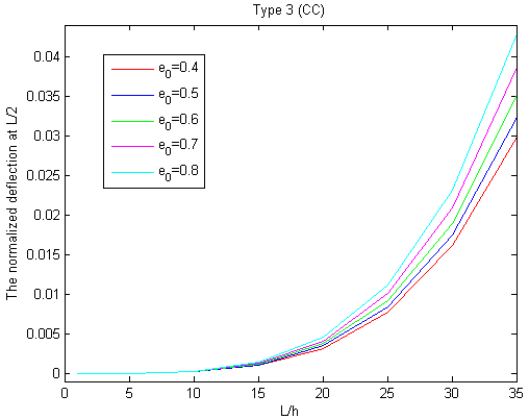

Figure 11. The deflections of type 3 (CC) porous beam by changing ratio L/h and porosity factor e_0

Thirdly, by changing the boundary condition from (CC) to (CS) and (CF), the bending behaviors of FGP beams can be seen in Figures 5-7 for three types 1, 2 & 3. Once again, the effects of porosity on the bending behavior of this structure are clearly presented in these figures. Furthermore, Figure 8 depict the influence of porosity on the deflections of (CF) porous beams for type 1, type 2 and type 3 respectively.

Finally, by varying the porosity coefficient e_0, the length to thickness ratio *L/h* and three types 1, 2 & 3, the results of the normalized transverse displacement $\overline{w} = w(L/2)/h$ at position *L/2* of FGP beams with (CC) boundary condition are plotted in Figure 9-11. As the porosity value increases, the deflection of FGP beam also increases and this statement holds for all cases.

CONCLUSION

In the paper, the bending behaviors of functionally graded porous (FGP) beams under three different types of boundary condition and three kinds of porosity are presented. The verification results of this paper are in good agreement with other results in reference. The topic and approach of the paper are simple, the main aim of the author is to affirm the applicability of the simple beam theory to analyze the functionally graded porous (FGP) beams with acceptable results.

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[1.]K. W. SALEEMAN, [2.]H. K. IBRAHIM, [3.]Y. O. BUSARI, [3.]Y. L. SHUAIN-BABATA,
[1.]A. G. ADUAGBA, [3.]A. S. ADEGBOLA, [3.]K. S. AJAO, [3.]I. O. AMBALI

DEVELOPMENT OF FUNCTIONAL OIL-ADSORPTION MATERIAL FROM WATERMELON RIND FOR REMEDIATION OIL SPILL RELATED POLLUTION

[1.]National Agency for Science and Engineering Infrastructure (NASENI) Abuja, NIGERIA
[2.]Department of Mechanical Engineering, University of Ilorin, Ilorin, NIGERIA
[3.]Department of Material and Metallurgical Engineering, University of Ilorin, Ilorin, NIGERIA

Abstract: The cost of common sorbent materials are relatively low but have poor recyclability, absorption capacity and are not environmentally friendly. Agricultural products are now been utilized as a substitution for environmentally friendly and low-cost oil sorbent materials. The present study aimed to develop and investigate the oil adsorption efficiency of modified watermelon rind for remediation of oil-contaminated water pollution. The particle size of the adsorbent was determined using mesh sizes of 0.3-1 mm. The pyrolysis experiments of Watermelon rind were carried out within the temperature range 250–700 ^{0}C. The composition of the pyrolyzed watermelon rind (PRA) was determined and functionalized with Methyltrichlorosilane (MTCS) and Methyltrimethoxysilane to form an improved oleophilic and hydrophobic surface. The adsorption properties and morphology of both adsorbents were characterized using FTIR and SEM respectively. Adsorption capacity, dose, and recyclability tests were carried out on three adsorbates (Motor oil and diesel fuel, and vegetable oil). The result showed that functionalizing the PRA improved the performance of the adsorbent with increasing oil adsorption capacities and oil selectivity. The findings also showed that oil recoverability and sorbents recyclability is possible with this material especially recovering with hexane.

Keywords: Functionalized, Pollution, Adsorption, Recyclability, Pyrollised

INTRODUCTION

The frequent occurring environmental pollution during accidental discharge of oil resulted in severe environmental damages. This can be sited from the recent devastating oil spillage at Venezuela, Mauritius, and Canada across the ocean. In the quest to provide an effective control of oil contamination from water, the use of adsorbents has been gaining attention (Asadpour *et al* 2015). The cost of common sorbent materials are relatively low, most of which the raw materials are from natural organic fibers (straw, wool, cotton), inorganic materials (zeolites, activated carbons, clays), and synthetic organic polymers (polypropylene, alkyl acrylate copolymers). Application of these materials have been reported with poor recyclability, absorption ability, degradability, and not eco-friendly. Some synthetic sorbent materials with excellent sorptive properties (graphite foams, graphene, carbon nanotubes sponges, aerogels or hydrogels, and hydrophobic polymer coatings on polyurethane sponges) are very expensive and harmful due to the required fabrication process with complex equipment (Zamparas *et al.,* 2020).

Currently, agricultural waste materials that also contributed to the environmental hazards are considered for sorption process due to its abundancy, eco-friendliness, and biodegradability properties. The materials have been reported with poor sorptive properties and can be enhanced by modification techniques using chemical, mechanical, and thermal modification approaches that include pyrolysis treatment of sorbent materials which involved treatments at temperatures above 700 °C, or functionalizing the pre-processing or post-processing modified sorbent materials with coating additives (Stolz *et al.,* 2016).

A study by Uzunov *et al.* (2012) reported the effects of the pyrolysis process on the oil sorption capacity of rice husk. The results show that the oil sorption capacity at a moderate temperature, 480 ◦C, is moderately influenced by the porous structure and promoted the sorption of oil and oil products in aqueous media. Behnood *et al.* (2016) examined the crude oil sorption capacity with raw sugarcane bagasse and acetylated sugarcane bagasse. It was concluded that the acetylated bagasse was significantly more oleophilic than the raw bagasse and the acetylation reaction increased bagasse oil sorption capacity by about 90%. Tang *et al.* (2018) modified wheat straw with palmitic acid as an efficient oil spill adsorbent. The capacity of pretreated wheat straw (PWS) and esterified wheat straw (EWS) was only 7.13±0.86 g/g and 14.00±0.50 g/g and this showed strong hydrophobicity and rapid oil absorption during the initial 20 s. Bayık and Altin (2018) utilized industrial waste to produce an oil sorbent by coupling it with functional silane coatings. The percentage of water sorption for uncoated and surface coated sorbent with (3-Aminopropyl) triethoxysilane (APS) and 10% for 3-(Trimethoxysilyl) propyl methacrylate (MPS) were 38.24% and 9.27% respectively. The results showed that industrial waste is promising oil sorbing material by silane coupling. El Gheriany *et al.* (2020) evaluated the oil sorption capacity of dried raw orange peel waste (OP) and thermally modified (300 ^{O}C and 500 ^{O}C) orange peel waste (TMOP). The results have indicated the water uptake of the TMOP is significantly higher than OP with better oil retention characteristics. The use of watermelon rind has been utilized

as adsorbent for the removal of heavy metal ions. It has been reported WR contained pectin, citrulline, cellulose, proteins, and carotenoids which are rich in functional groups such as hydroxyl (cellulose), amine (proteins), and carboxylic (pectin) that are hydrophilic groups, making it to adsorb organic pollutants. However, no research has consider the use of modified Watermelon rind for oil contaminated water sorption process. The present study aimed to develop and investigate the adsorption behavior of modified functional watermelon rind for remediation of oil contaminated water pollution.

MATERIALS AND METHODS

— Preparation of Modified Adsorbent Material

The Watermelon rind were obtained from local stores in Coventry city UK. The rind was shredded, transferred to a tray and washed severally with distilled water to remove physical impurities. The washed samples were dried at 60°C for 48hours in vacuum to less than 5% moisture content and grinded and mechanically sieved to 0.3-1 mm particle size and lower as shown in Figure 1. The dried sample was put in an evaporating basin of 14.5cm x 7cm hollow furnace for pyrolysis treatment. The pyrolysis of was carried out in two batches as reported by Jiao, Wan and Li (2016). The first batch of the dried sample was held at temperature of 500°C for 1 hour and raised to 700°C for 2 hours and allow cool to room temperature and a black ash-like substance was obtained. The second batch of the dried sample was held at temperature of 700°C for 1hour, then raised to 1000°C for 2hours and white ash-like substance (PRA) was obtained.

Figure 1: dried and Pyrolysed (Modified) watermelon rind

— Preparation of Functionalized Samples

The modified Watermelon rind was coated with Methyltrichlorosilane (MTCS) and Methyltrimethoxysilane, and then poured into a tea bag to improve the functional hydrophobic properties. Then 200 mL of toluene was added to the particles as the reaction solvent. Besides, a beaker of MTCS solution was prepared with addition of 2, 3 and 4 mL of MTCS and MTMS in10 mL of ethanol. The obtained solution was added to the tea bag dropwise under a nitrogen atmosphere and agitated for 5 h. After reaction, the sample was dried in an oven at 60°C. The pyrolised watermelon rind was functionalized with 10 ml MTCS and 10 mL MTMS was briefly named as functionalized samples (FRA) shown in Figure 2.

Figure 2: Settling Unfuctionalised and Floating Functionalised PRA in Water

— Preparation of the Adsorbate

50mL of deionized water was measured in a 100mL measuring cylinder and transferred into a 200mL glass beaker. The motor and diesel oil SAE 20W/50 of low and medium viscosity as reported by Senanurakwarkul *et al.* (2013) with physical properties (Density and Viscosity) in Table 1 were purchased from PTT (Thailand) Co., Ltd. The 5ml of diesel oil and machine oil stained with Sudan red were mixed separately with the measured deionized water by agitating the mixture on a flask shaker for 30 minutes as carried out by Husin *et al* (2011). Each beaker was labelled accordingly.

Table 1: Adsorbate Physical Properties

Oil Type	Density (g/cm^3)	Viscosity (cP)
Mortor Oil	0.92	133
Diesel Oil	0.832	210.4

— Experimental Analyses

The morphology of the surface of the PRA and that of FRA were observed by scanning electron microscopy (SEM) using JEOL JSM 6390 microscope applying the appropriate magnification. The amounts of the dispersed fluids were determined by extraction with acetone. The determination of the organic compounds composition of the acetone extract from raw watermelon rind has been carried out using a GCMS-QP2010 PLUS, SHIMADZU, JAPAN equipped with a mass spectrometric detector (GC/MS). The obtained organic compounds were also characterized using Fourier transformer infrared (FTIR) spectroscopy (FTIR- 8400S instrument). The infrared spectra were recorded on a Nicolet Avatar 360 spectrometer in a tablet KBr at a spectral resolution of 2 cm^{-1} and scanned in the 4000–400 cm^{-1} range.

Batch adsorption experiments for the samples were carried out using pure oil and oil-water solution. Ranges of adsorbent mass (0.5g, 1.0g, 1.5g and 2.0g) were prepared in tea bag, weighted and dipped in the pure oil at interval of 10minutes. At drip time of 1minutes, the mass of the adsorbent was measured using ASTM F 716–09 standard for oil sorption capacity of the pyrolysed and functionalsed samples to calculate sorption capacity by dividing the final mass after oil sorption by the initial mass before sorption.

The adsorbent was then taken out with a tweezer and the final concentrations were calculated using equation 1. The experiment was conducted at 30 ^{O}C room temperature and at 45–55% relative air humidity.

Mechanical squeezing was first conducted for recyclability on the two sorbents by squeezing with two pairs of tweezers to recover the different oil and reuse material. Thereafter, the adsorbent was weighed before reapplying immediately for another sorption cycle. This process was repeated until each adsorbent could no longer undergo more adsorption. A second method adapted from EPA method 9071B was applied by washing the adsorbents in n-hexane for four hours using soxhlet. This was done by putting the adsorbent in an extraction thimble and thereafter measuring 150mL of n-hexane into a 250mL round bottom flask which had boiling chips put in it. The soxhlet apparatus was set up to get the heating to a cycling rate of 20 cycles per hour and this was done for four hours to extract the oil out of the sorbent. The n-hexane washed adsorbent was then placed in an oven to dry. The adsorbent was reweighed before using for another cycle of adsorption. This was repeated for every cycle of recyclability. The oil used in this test was motor oil. Subsequently, the extract was decanted to another round bottom flask and attached to a rotary evaporator for 15 minutes in order for the n-hexane to evaporate. Thereafter, the residue oil was recycled for reuse.

RESULT AND DISCUSSION

— Characterization of adsorbent

The composition of organic substances watermelon rind was obtained from GC/MS analysis. The Relative abundance organic compounds has been reported to contained two phases that include low molecular weight of organic oxygen-containing compound (acids, aldehydes, esters, ketones, and phenols) and a phase that contained water-insoluble organics (alkenes, arenes, and cycloalkenes) of high molecular weight (Uzunov *et al.,* 2012). The extract of watermelon rind is characterized with ten major and abundant compounds as shown in Figure 3.

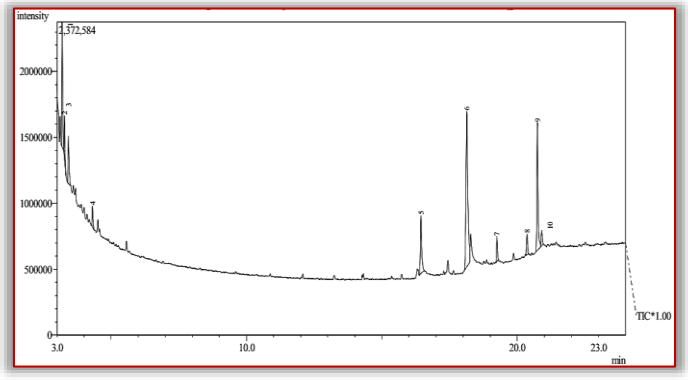
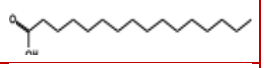
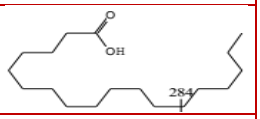
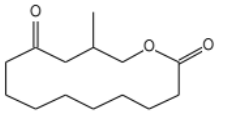
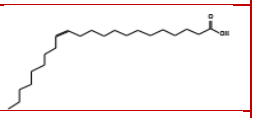
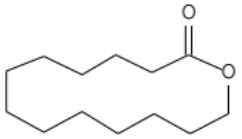
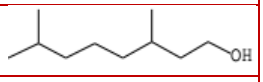
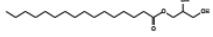
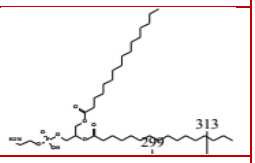
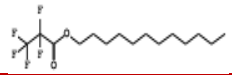


Figure 3: Chromatogram of Watermelon Rind Extract

Table 2 shows the result obtained in GCMS bands of watermelon rind which contained mainly variety of organic oxygen-containing compounds with higher molecular weight. This showed the reason for poor sorptive properties that required modification techniques such as pyrolysis and esterification to obtain water-insoluble organic compounds.

Table 2: Major Organic Compounds name and their structure obtained from GCMS

S/N	Compound Name	Formula	Molecular Weight	Compound Structure
1	Pentadecanecarboxylic acid	C16H32O2	256	
2	Octadecanoic acid	C18H36O2	284	
3	3-Methyloxacyclotetradecane-2,11-dione	C14H24O3	240	
4	Erucic acid	C22H42O2	338	
5	Oxacyclotetradecan-2-one	C13H24O2	212	
6	3,7-Dimethyl-1-octanol	C10H22O	158	
7	2,3-dihydroxypropyl ester	C19H38O4	330	
8	Hexadecanoic acid	C37H74NO8P	691	
9	Z,E-2,13-Octadecadien-1-ol	C18H34O	266	
10	Pentafluoropropionic acid	C18H31F5O2	374	

The pyrolysis process involved increasing temperature that lead to deterioration of oxygen compounds that forms large amount of high molecular weight alkanes with low temperature increment whereas at higher temperature, compounds of lower molecular weight are formed.

The adsorption characteristic of modified watermelon rind was conducted with FTIR. The FTIR showed the transmittance spectral of organic compound that displayed many peaks indicating different functional groups. The spectral for raw watermelon rind has been reported with a broad peak at 3635 cm-1 assigned to O–H stretching vibrations (polyphenolic group), 2910 to C–H stretching vibration of the methyl and methoxy groups. The peak at 1730 cm-1 assigned to C=O stretching vibration of acid derivatives, and the weak band at 1310 cm-1 is attributed to amide groups (Prasad *et al.,* 2015). However, the intense peak corresponds to –OH (hydroxyl) stretching vibrations, for the modified WR showed in Figure 4 was obtained at 3427.62 cm−1. The peaks at 2932.86 cm−1 assigned to C–H, peak at 1631.83 cm−1 corresponds to C=O stretching of

carboxylic acid groups or esters, and asymmetric and symmetric vibrations of ionic carboxylic groups (–COO–), respectively, appeared at 1432.19 and 1080.17 cm−1. These results suggest that WR predominantly contain organic functional groups such as hydroxyl, carboxyl and carbonyl groups. Meanwhile, the change in the spectral values indicate the destruction processes during the thermal cracking of lignocellulose materials.

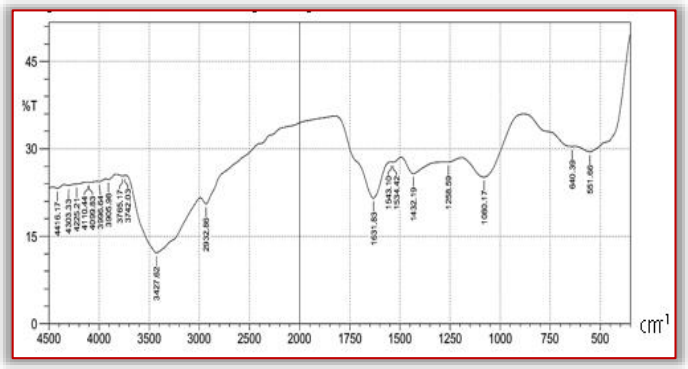


Figure 4: Spectrogram of Modified Watermelon Rind

The results from the spectral analysis showed that functional groups intensity decrease with increasing the pyrolysis temperature which resulted to formation of some volatile compounds like cellulose and lignin. It has been reported that cellulose, and lignin build a stable porous structural units that have an optimal affinity for hydrophilic and hydrophobic liquids (Mahmoud, 2020) but decomposed within the temperature interval 300–400◦C and above 400◦C for lignin. The destructive reactions has been attributed to decreasing polymerization degree like depolymerization, hydrolysis, oxidation, dehydration and decarboxylation (Uzunov *et al.,* 2012). This thermal degradation lead to the formation of more stable condensed structures with pores to accommodate oil substances.

The morphology of the different adsorbent was characterized using SEM operating at 10.00kV as shown Figure 5. The SEM image of the PRA has a unified structure compare to the FRA which shows an infinite porous structure. These differences in the functionalized materials compared to their unfunctionalized form could be attributed to the effect of salination on the materials by creating a non-polar interphase for increased oil sorption.

— Effect of Functionalization on Absorption

Hydrophobic property and affinity of sorbent material to adsorb oil and organic solvent can be effective with modification approach like pyrolysis process which make it hydrophilic and functionalized to induce hydrophobicity. It can be observed in Figure 6 that adsorption capacity of FRA sorbent with two adsorbate is higher than the PRA material.

The adsorbent adsorbed the water to a saturation point with an adsorption capacity of 3.4420g/g and the hydrophobicity increased by 70.3% with water adsorption capacity of 1.0215g/g by functionalizing the PRA with MTCS. This was as a result of the silanation reaction between chlorosilane and water molecules that are loosely combined with the surface of the PRA. Thus, presented a great number of accessible sites and high surface energies with non-polar interphase by eliminating the hydroxyl groups (Makowski *et al.,* 2014).

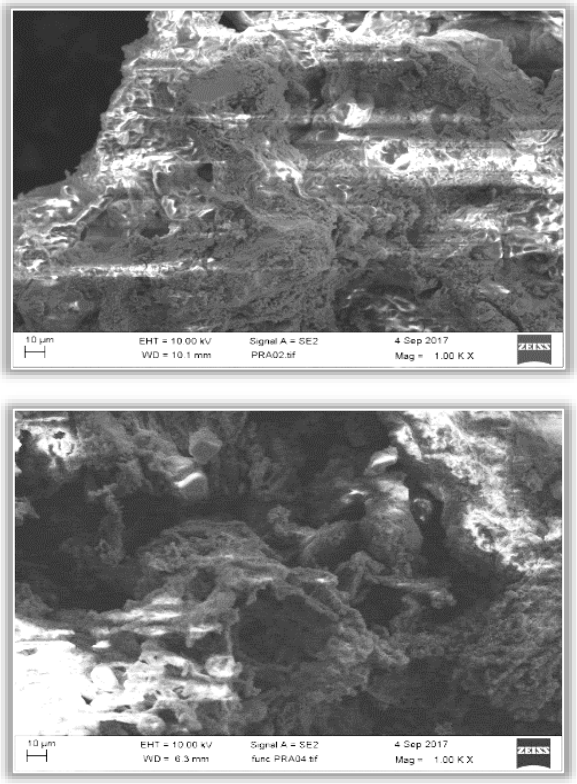


Figure 5: The Morphology of Pyrolysed (Modified) and Functionalised Watermelon Rind.

The result of functionalization on the PRA is in consistent with findings of Wang *et al* (2012) where dodecyltrimethoxysilane (DTMS) was used to functionalize Kapok fibre. The oleophilicity increased by 46.6% for diesel oil sorption and 20.2% for soybean oil sorption. However, the water adsorption capacity of the MTCS functionalized PRA is lower than that functionalized with MTMS. Compared to MTCS coated samples, MTMS functionalized PRA had a water adsorption capacity of 0.3339g/g. The better performance of MTCS over MTMS may be because the latter is synthesized from the former, hence has a lower concentration (Latthe *et al* 2012).

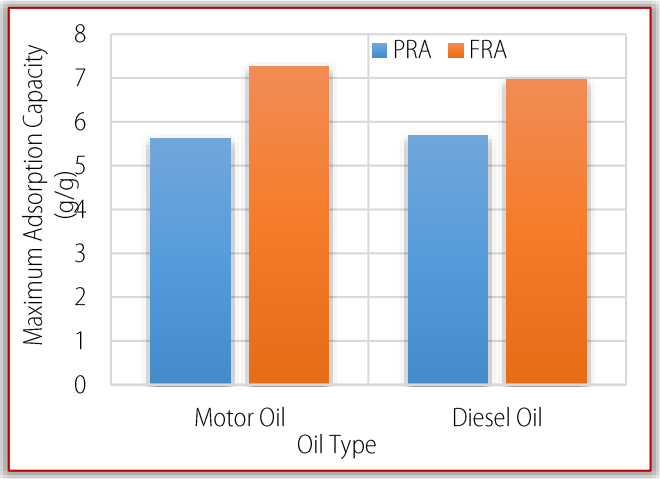


Figure 6: A comparison between PRA and FRA for motor oil, and diesel oil.

— Effect of Contact Time on Oil Sorption Capacity

The experimental data were measured at 60 minutes, with an interval of 10 minutes and the effect of time on sorbents with oil-contaminated water was established as shown Figure 5. From the result for all the two oil types (motor oil, and diesel oil), there is an increment in adsorption capacity with increasing contact time for PRA, and FRA. The fastest rate was observed between the first 10minutes and 20 minutes. This is in line with the result reported by Behnood *et al* (2016) that fastest sorption was achieved at an early stage due to the high porosity of the sorbent. Thereafter, the adsorption capacity continued to increase but at a slower rate till the 50th-60th minute. This adsorption trend could be due to plain active sites on the adsorbent surface which then got to saturation phase later with time as more oil molecules are taken up by the initial plain sites and led to slower rate of adsorption and this is consistent with the findings of Mahmoud (2020); El Gheriany *et al.,* (2020).

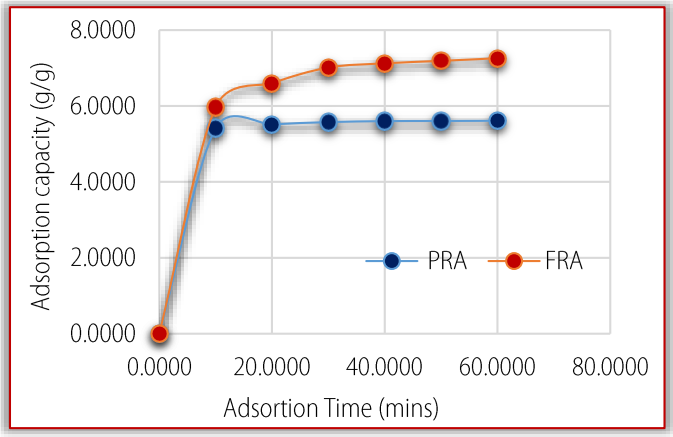


Figure 7: Effect of adsorption time of PRA and FRA on Motor Oil

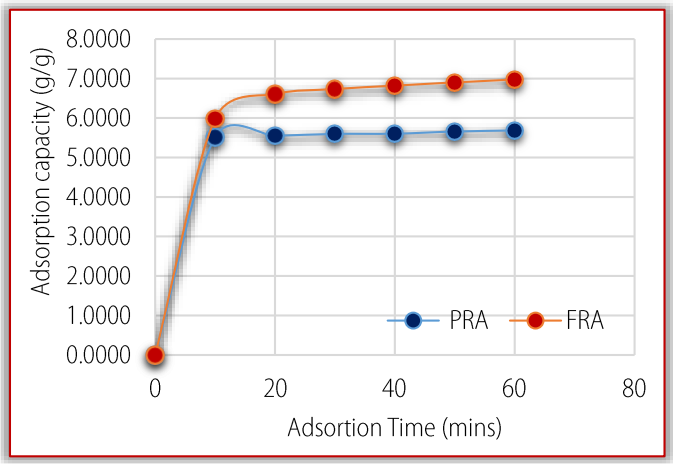


Figure 8: Effect of adsorption time of PRA and FRA on Diesel Oil

It can be revealed in Figure 7 and 8 that PRA and FRA had their optimum adsorption at 60 minutes contact time. For motor oil, an optimum adsorption capacity of 5.6108g/g, and 7.2560g/g for PRA, and FRA respectively were observed. Whereas for diesel oil, maximum adsorption capacities of 5.6860g/g, and 6.9760g/g were obtained for PRA, and FRA respectively as shown in Figure 8.

— Effect of Initial Concentration of Oil

The initial oil concentration was used to study the percentage of adsorbed oil concentration under optimized condition of 60 minutes contact time and 0.5g adsorbent. Using 100mL of water, varying initial oil concentrations of 25%v/v-45%v/v at an interval of 5%v/v were used to evaluate the effect of oil concentration on adsorption. From table 3, it showed that sorption capacity increased with increasing initial oil concentration; however, the percentage of oil adsorbed decreased by increasing initial oil concentration.

Table 3: Effect of Initial oil concentration on Motor and Diesel oil

Adsorbent	Initial oil concentration (%) v/v	Final oil concentration % (v/v)	Motor Oil removed (%)	Diesel Oil removed (%)	Motor Oil Adsorption capacity (g/g)	Diesel Oil Adsorption capacity (g/g)
PRA	25	21.5	14.0	12.4	5.5322	4.9000
	30	26	13.3	11.7	6.3226	5.5322
	35	30.7	12.3	10.6	6.7968	5.8484
	40	35.7	10.8	10.5	6.8491	6.6387
	45	40.6	9.8	10.4	6.9548	7.4290
FRA	25	20.2	19.2	16.0	7.5871	6.3226
	30	25.1	16.3	13.7	7.7451	6.4806
	35	29.8	14.9	12.0	8.2193	6.6387
	40	34.6	13.5	10.6	8.5355	6.6703
	45	39.5	12.2	10.5	8.6935	7.4448

The percentage of oil removed for PRA on motor oil decreased by 4.2% as initial oil concentration increased from 25%v/v to 45%v/v. There was 7% reduction in oil removed percentage for FRA on motor oil from the lowest initial oil concentration to the highest initial oil concentration. The same trend was encountered for diesel oil where oil removed for PRA reduced by 2%, and FRA by 6.5%. A similar trend was reported by Tiwari (2011) and attributed the reduction in percentage of oil removed to an increase in number of oil molecules while adsorbent amount remains the same. However, increasing adsorption capacity per unit mass of the adsorbent with increasing initial oil concentration could be as a result of available active sites that were not possible at low concentration and utilization of adsorption surface (Razavi *et al.,* 2014).

— Oil Recoverability and Recyclability

Adsorption recyclability is another vital property to investigate the beahviour of an adsorbent. This contributed towards saving cost, reduction in waste generation and energy saving in production process. The sorbent materials showed some contents of oil adsorbed in sorbent material and some incomplete removal of oil as the mass of the reweighed sorbents increased by 20-25% of the initial weight of the dry sorbent. The optimum capacity of the PRA and FRA decreased by 40% and 45% respectively showed in Figure 9. The decrease in adsorption capacity can be attributed to the damage of porous structure and also the increased remnant mass (Brindha *et al.,* 2019).

Secondly, the motor oil-adsorbed material was washed with hexane and oil was recovered in a rotary evaporator. After six cycles, the PRA could no longer undergo recyclability as observed in Figure 10. The adsorption capacity of hexane washed FRA at the fifth cycle was even slightly higher than that recorded at the second cycle when mechanical squeezing was applied.

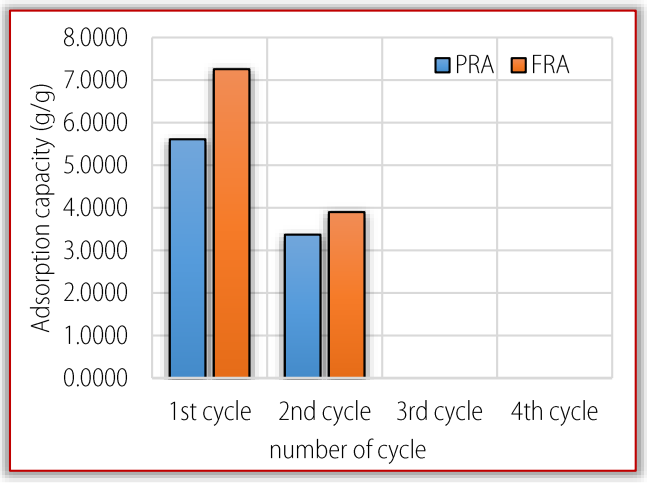


Figure 9: Recyclability of PRA, and FRA by squeezing

This could be due to its hydrophilicity which allowed FRA to move with two more times up to the eighth cycle. There was insignificant weight gain in the reweighed sorbent samples after being washed with hexane and dried in an oven. This showed excellent oil recoverability which was confirmed when the recovered oil was weighed after separation from hexane in a rotary evaporator.

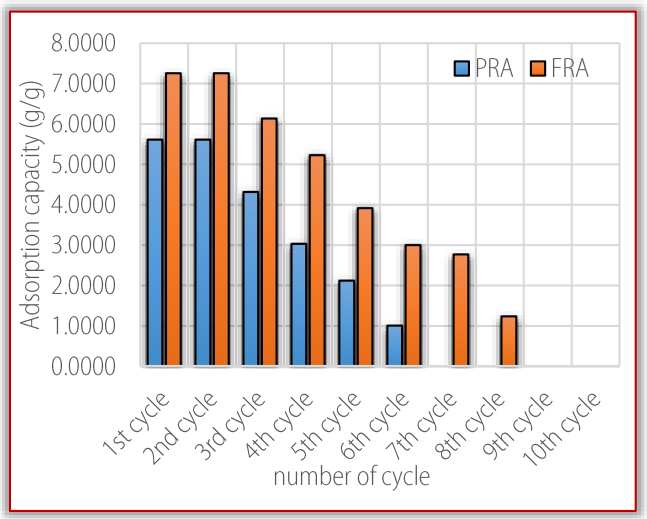


Figure 10: Recyclability of PRA, and FRA using hexane as solvent

The oil recovered was about 0.2% less of the initial mass of oil that was adsorbed by the adsorbent. The excellent recyclability could be attributed to high oil recoverability which gave room to more sites for adsorption compared to mechanical squeezing. From Figure 10 below, it can be seen that reduction in adsorption capacities tends to be higher as recyclability increase; this reason could be attributed to damage of porous structures as reusability increases (Alaa El-Din *et al.*, 2017). Although squeezing the oil is very energy efficient but eventually, the free space for adsorption is progressively restricted as a result of damaged porous structure and retained oil. In comparison, El Gheriany *et al.* (2020) established that the process enhanced removal of oil leaving behind not more than 0.5% of the residual oil.

— Influence of Adsorbent Dose

The influence of adsorbent quantity was studied using ranging mass of adsorbent from 0.5g to 2.0g at an interval of 0.5g. This was studied in motor oil, and diesel oil using PRA and FRA adsorbents.

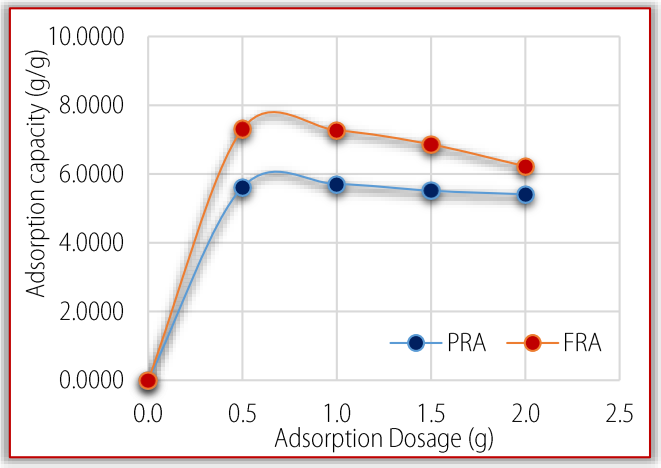


Figure 11: Influence of adsorbent dose on PRA and FRA.

From the Figures 11, it can be observed that adsorption capacity initially increased with increasing adsorbent dose. However, this decreased with further increase in adsorbent dose. An optimum adsorption capacity of 8.1206g/g and 8.4995g/g at 1.0g adsorbent dose was observed for the PRA and FRA respectively in vegetable oil. This same attribute was obtained for diesel oil. A similar trend was observed by Aljeboree *et al.* (2014) in the study on the adsorption of textile dyes using activated carbon from coconut shell. Though the adsorption capacities tend to reduce with increasing adsorbent dose, the amount of oil adsorbed continued to increase with increasing dose of adsorbent till the last dose of adsorbent was applied. The initial increase in adsorption capacities could be explained to be attributed to the presence of higher active sites at a lower concentration of adsorbent dose (Padmavathy *et al.*, 2015). Consequently, the further reduction in adsorption capacities with an increase in adsorbent dose could as well be attributed to the unsaturated adsorption sites during adsorption reaction. Further increment in concentration of adsorbent dose may cause aggregation of adsorbent. The increase in the amount of oil adsorbed could be understood from the fact that increase in adsorption dose increases the number of available adsorption site (Shahul *et al.*, 2017).

CONCLUSION

It can be deduced that the adsorption capacities of sorbents is affected by a lot of factors; ranging from the concentration of the spilled oil to the time of contact of adsorbent with the adsorbate. The experimental analyses showed that functionalizing the pyrolysed watermelon rind with MTCS improved the performance of the two adsorbents by

increasing the oil adsorption capacities and oil selectivity. The findings also showed that oil recoverability and sorbents recyclability is possible with these materials especially recovering with hexane. Therefore, MTCS functionalized watermelon rind can be proposed as a sorbent material for oil spill clean-up in wetlands and aquatic areas.

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[1.]Ştefan Mihai ŞEFU, [1.]Bogdan Alexandru TUDOR, [1.]Radu Iulian RĂDOI, [1.]Ioan BĂLAN, [2.]Mario CRISTEA

OPTIMIZING CONSUMPTION IN AGRICULTURAL MACHINES AND INSTALLATIONS BY USING DIGITAL HYDRAULICS

[1.]INOE 2000 – Subsidiary Hydraulics and Pneumatics Research Institute (INOE 2000-IHP) Bucharest, ROMANIA
[2.]National Institute of Research – Development for Machines and Installations Designed to Agriculture and Food Industry – INMA, Bucharest, ROMANIA

Abstract: In this article, the authors propose two solutions of digital hydraulic equipment for their use in agricultural machines. The proposed pieces of equipment are: (1) a Digital Hydraulic Pumping System (DHPS) consisting of 4 fixed flow pumps driven by a biaxial motor, 4 3/2 on/off electrohydraulic directional valves connected on the pump outlets, a 4/2 control valve, 4 one-way valves and a rotary hydraulic motor and (2) a Digital Flow Control Unit (DFCU) consisting of 5 electrohydraulic directional valves type 2/2, of different flow rates, connected to a fixed flow pump, connected to a hydraulic motor. The two digital systems are simple, reliable and are serviced by electronic control modules (ECUs), which send signals to close or open the on/off type electrohydraulic directional valves depending on the operator's commands in the cab. Due to these characteristics, the systems can obtain a flow regulation with lower energy losses, compared to the classic hydraulic systems that use a resistive regulation (with high energy losses), so that the consumption of agricultural equipment is also reduced. Authors will present the achievements obtained after the simulation of the two digital hydraulic systems.

Keywords: digital hydraulic, efficiency, agricultural industries, numerical simulation, hydrostatic transmission

INTRODUCTION

In recent years, the big problem in hydraulics has been to reduce energy losses, thus reducing CO_2 emissions into the atmosphere. Numerous studies and articles have shown that hydraulic systems are high energy consumers and about 30% of the energy consumed is lost by transforming it into heat. In general, a large part of the hydraulic energy is dissipated on the internal energy losses and on the valves.

The current trends of the industry are the reduction of energy losses in hydraulic systems, but keeping the technical specifications at a high level *(Scheidl et al., 2012)*.

In the 21st century agriculture, agricultural machines and equipment are a vital component without which agri-food production could not meet current demand.

Most agricultural machines have one or more hydraulic systems. These become very complex from a constructive point of view.

Digital hydraulics is a relatively new concept, and it is developed by teams of researchers such as those led by Scheidl et al., (2012), or Linjama (2011), and companies *(Hyöty, 2012)* such as Artemis and Bosch-Rexroth. The possibility of developing digital hydraulics arose with the development of electronic systems, so that more reliable hydraulic equipment could be created.

According to Zang et al., (2020), the main features for digital systems are:

- ≡ Active control of outputs.
- ≡ Use of electrohydraulic directional valves on/off type.
- ≡ Intelligent system control (use of microprocessors or PLCs).

Digital hydraulic systems are divided into:

- ≡ Systems with several electrohydraulic directional valves connected in parallel coded using different series:
  - o Encoding using binary series 2, 4, 8, 16… etc., or Fibonacci number is called Pulse Code Modulated (PCM).
  - o Coding using series 1, 1, 1, etc. is called Pulse Number Modulated (PNM).
- ≡ Hydraulic systems that use a single PWM operated electrohydraulic directional valve where the flow variation results from the sum of the open or closed periods.

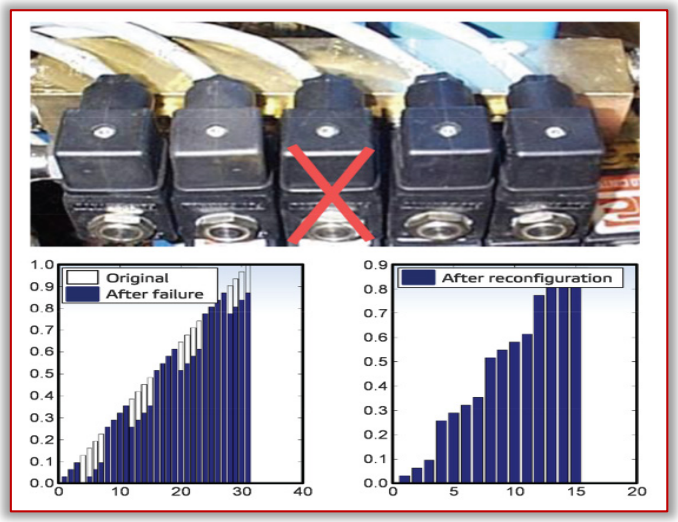


Figure 1 - If one electrohydraulic directional valve fails, the remaining valves are automatically reconfigured to produce a response curve that allows the machine to continue to run (***wpp_digihydraulics)

The advantages of digital hydraulic systems are:

- ≡ Due to the fact that digital systems use simple electrohydraulic directional valves that do not have high requirements on the working fluid, they increase the reliability of the system.
- ≡ Using a programmable logic controller (PLC) and the fact that several components are used to adjust it, if one of

them fails, the system will still be able to operate, even if not with the same high characteristics, as one can see in figure 1.

≡ The acquisition cost is lower than other servo or propo systems.

The disadvantages of digital hydraulic systems are:

≡ There are pressure shocks when switching the electrohydraulic directional valves, but this can be solved by using a hydro accumulator.

≡ The adjustment is made in discrete points, not continuously as the servo and propo equipment do.

A representation of a DFCU with n on/off electrohydraulic directional valves system can be seen in figure 2 *(Drumea et al., 2016)*.

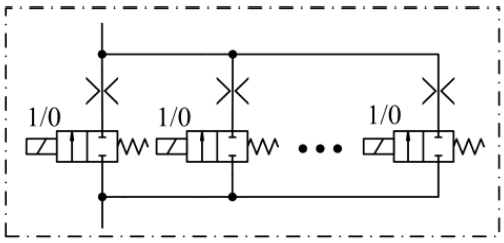


Figure 2 – Digital Flow Control Unit

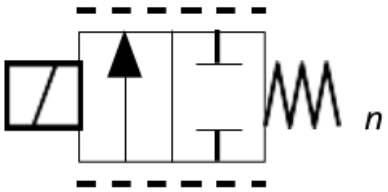


Figure 3 – Simplified symbol of DFCU

The simplified representation of the DFCU can be seen in figure 3, where „n" is the number of electrohydraulic directional valves that the system is composed of.

To implement a parallel connected DHPS, there are two independent ways, one of them is based on the direct control of the pump pistons (for the radial hydraulic pumps or motors *(Drumea et al., 2016)*), and the other is based on controlling the outputs of serval hydraulic pumps, which have a fixed geometric displacement (*Linjama, 2011; Locateli et al., 2014*).

For the implementation of the parallel connected DFCU, the authors have chosen the binary encoding method, of five electrohydraulic directional valves, with five different flows.

The simulation of the two digital systems was done with the help of the AMEsim software, and obtaining table for flows, showing in this way, that variable flow can be achieved with digital hydraulic systems, at low energy consumption.

MATERIALS AND METHODS

The digital systems proposed by the authors are equipment consisting of components of different capacities, which are in a binary progression of the form 2,4,8,16 ... etc., which can be practically called 2^n, where „n" is the number of electrohydraulic directional valves/pumps. Using the calculation formula 2^n-1, we can obtain the number of discrete points of flow variation for each system *(Mantovani et al., 2016)*.

Presentation of the systems sketches

Next, we will present two digital hydraulic systems:

≡ Digital Hydraulic Pumping System (DHPS) with four fixed capacity pumps with cylindrical capacity in binary progression. Using the formula 2^n-1, where n = 4, we obtain 16-1 = 15 discrete points of variation of the flow.

≡ Digital Flow Control Unit (DFCU) with five on/off electrohydraulic directional valves of different flow rates, also in binary progression, where a flow variation can be obtained in 31 discrete points. Using the formula 2^n-1, where n = 5, we obtain 32-1 = 31 discrete points of variation of the flow.

DHPS System

The DHPS system consists of four fixed flow pumps with coded capacities using the binary series P1-P4, an internal combustion engine marked M with a speed of 750 rpm, four on/off type electrohydraulic directional valves (DV1-DV4) with inactivated position that has the consumers connected to the tank to manage the energy losses when the equipment is in standby. Four CV1-CV4 direction valves, DV5 hydraulic motor direction selector valve HM, a flow transducer marked FM, a pressure transducer PT, Programmable Logic Controller (PLC) that drives the whole process. The system is also equipped with a filter F and a safety relief valve RV.

System operation:

The system is designed not to consume much energy when the equipment is in standby and is suitable for either applications with hydraulic cylinders or hydraulic motors.

When the operator wants to start the movement, he sends a command to the PLC, which in turn selects one or more DV1-DV4 electrohydraulic directional valves to achieve the desired flow by the operator.

When the equipment is not used, the four pumps send all the flow to the tank at low pressure, so that the pressure loss is minimal.

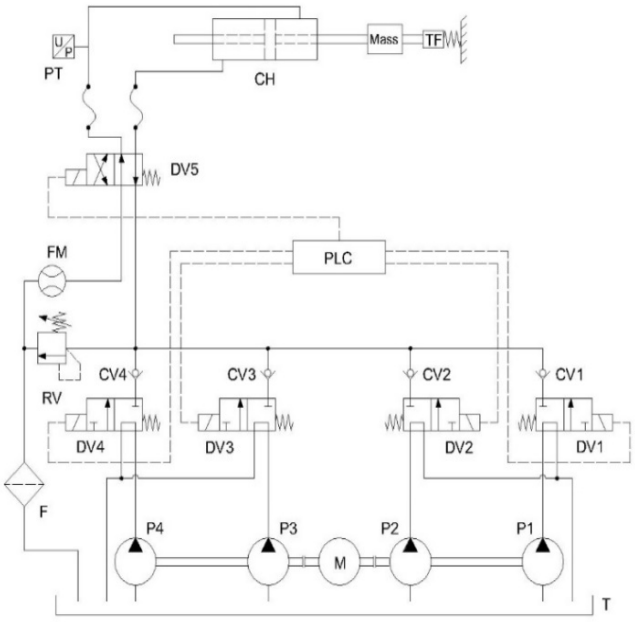


Figure 4 - Hydraulic diagram of the DHPS system with 4 binary coded pumps

Modeling the DHPS drive system

The hydraulic circuit was modeled in AMESim. The hydraulic components have the sub-models in table 1 and the parameters value are shown in table 2.

Table 1. Components of sub-models in the simulation

Component	Sub-model
Pump	PU001
Directional valve 3/2	HSV23_01
Directional valve 4/2	HSV24_01
Dynamic time table	SIGUDA01
Hydraulic cylinder	HJ021
Pressure control	RV010

Table 2. Parameters of the simulation

Parameters		
Hydraulic Hose	Directional valve (2/3)	Relief valve
Pressure 1.013 bar	Flow rate 20 l/min	Cracking Pressure 250 bar
Diameter 10 mm	Pressure drop (ΔP) 5 bar	
Length 1 m		
Hydraulic pipe	Directional valve (2/4)	Hydraulic Cylinder
Diameter 10 mm	Flow rate 50 l/min	Piston diameter 100mm
Length 0.1 m	Pressure drop (ΔP) 5 bar	Length of stroke 1,5 m

The hydraulic pipes are modeled with the HL0000 sub-models, and the hoses are modeled with the HL0001R sub-model. The configured parameters for pipes and hoses are the nominal diameter and length. The system simulation sketch is presented in figure 5.

There are four electrohydraulic directional valve 3/2 type that control the output of each pump and 4/2 types electrohydraulic directional valve that controls the direction of the hydraulic cylinder. The electrohydraulic directional valves in the simulation have proportional valve sub-models, but in this case, they are controlled with maximum on/off signal. Static models have been adopted for electrohydraulic directional valves. The system safety relief valve has been set to 250 bar.

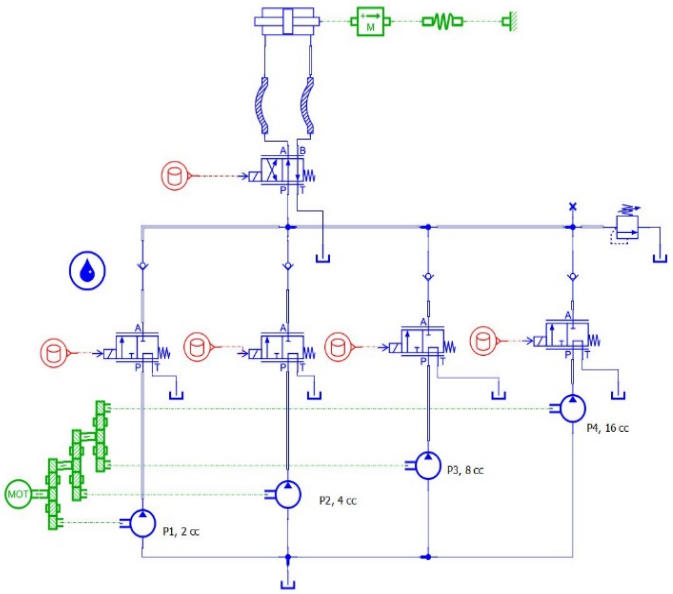


Figure 5 - DHPS system simulation scheme

Command step		OFF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
P1	2 cm³		■		■		■		■		■		■		■		■
P2	4 cm³			■	■			■	■			■	■			■	■
P3	8 cm³					■	■	■	■					■	■	■	■
P4	16 cm³									■	■	■	■	■	■	■	■
Total Vg (cm³)		0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30

Figure 6 - Variations of the total capacity of the geometric capacity of the pumps, for the 15 control stages

Dynamic time table blocks were used to control the pumps, which simulated the binary code for controlling type 3/2 electrohydraulic directional valves, to achieve the 15 flow steps.

DFCU system

The second system DFCU consists of: internal combustion engine marked M, Fixed Flow Pump (HP), Hydro accumulator (HA), electrohydraulic directional valve 2/2 (DV6), 5 electrohydraulic directional valves (on/off) DV1- DV5 type 2/2 which are transited by different flows in binary progression. DV7 electrohydraulic directional valve type 4/2 that changes the direction of rotation of the hydraulic motor. HM hydraulic motor, FM flow transducer, PT pressure transducer, Filter F. The PLC that controls the operation of the entire system.

This system is designed for applications where continuous operation such as adjusting the combine head is not required.

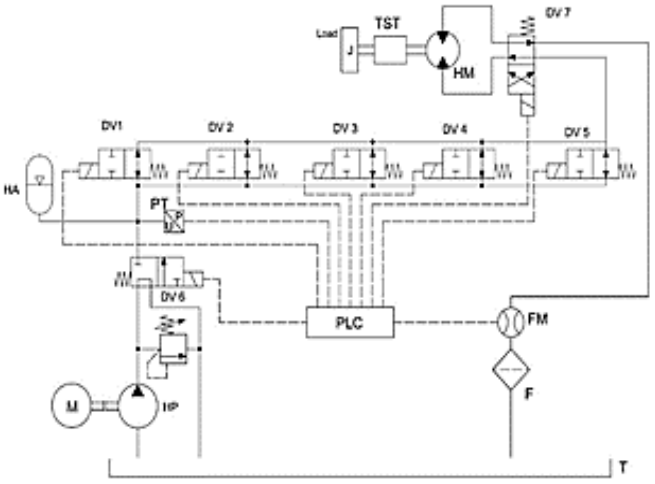


Figure 7 – Hydraulic diagram of the DFCU system with 4 binary coded electrohydraulic directional valves

The operation of the system is the following: the fixed flow hydraulic pump is a small capacity one and charges the hydro accumulator. When it is necessary to operate the system, depending on the speed desired by the operator, the PLC sends an order to one or more DV1-DV5 electrohydraulic directional valves. When the pressure in the hydro accumulator decreases, the PT transducer sends a signal to the PLC, so that the DV 6 electrohydraulic directional valve is actuated so that the pump sends flow into the system and implicitly into the hydro accumulator. When the pressure value has reached the set threshold, the

PLC takes control of the DV 6 electrohydraulic directional valve, and it moves to the main position, sending the flow supplied by the pump to the tank, with low energy loss.
Due to the hydraulic accumulator, the pump can be small, so that the energy loss is reduced, implicitly the consumption of the machine.

DFCU simulation

Figure 8 shows the simplified DFCU simulation scheme. A simplified simulation was performed in order to initially validate the principle of this DFCU. SC-1 to SC-3 are super components created to be able to operate the directional valves according to the actuation scheme presented in table 3.

Table 3. The condition of each electrohydraulic directional valve and the flow obtained for each of the 31 adjustment stages

Q State	q=2 [l/min]	q=4 [l/min]	q=8 [l/min]	q=16 [l/min]	q=32 [l/min]	Qt [l/min]
0	-	-	-	-	-	0
1	+	-	-	-	-	2
2	-	+	-	-	-	4
3	+	+	-	-	-	6
4	-	-	+	-	-	8
5	+	-	+	-	-	10
6	-	+	+	-	-	12
7	+	+	+	-	-	14
8	-	-	-	+	-	16
9	+	-	-	+	-	18
10	-	+	-	+	-	20
11	+	+	-	+	-	22
12	-	-	+	+	-	24
13	+	-	+	+	-	26
14	-	+	+	+	-	28
15	+	+	+	+	-	30
16	-	-	-	-	+	32
17	+	-	-	-	+	34
18	-	+	-	-	+	36
19	+	+	-	-	+	38
20	-	-	+	-	+	40
21	+	-	+	-	+	42
22	-	+	+	-	+	44
23	+	+	+	-	+	46
24	-	-	-	+	+	48
25	+	-	-	+	+	50
26	-	+	-	+	+	52
27	+	+	-	+	+	54
28	-	-	+	+	+	56
29	+	-	+	+	+	58
30	-	+	+	+	+	60
31	+	+	+	+	+	62

In order to be able to see the flow adjustment, a flow transducer was introduced at the exit of the five directional electrohydraulic valves.

In the simulation of this DFCU system, a constant pressure and flow source was taken into account in order to validate the operating principle of this system, and according to the simulation, it can operate in the system described in figure 5.

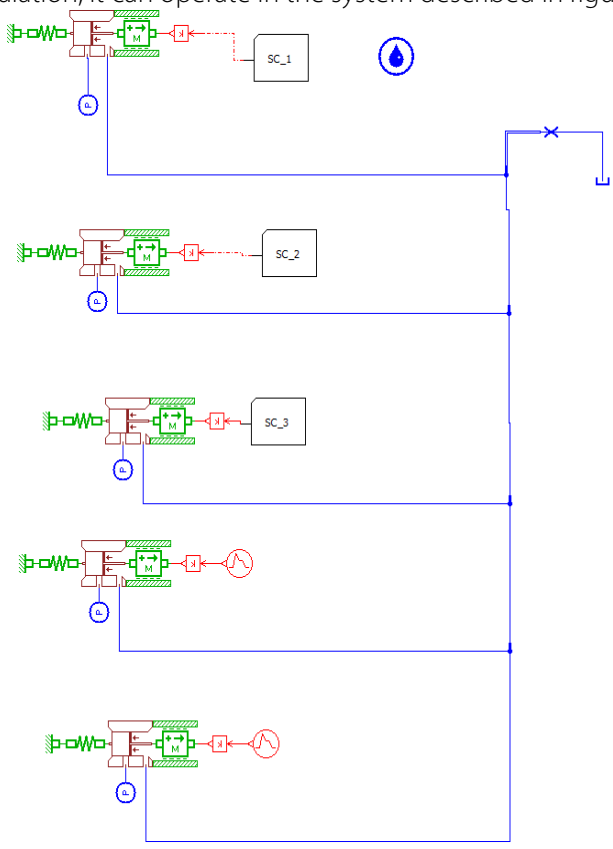


Figure 8 – DFCU system simulation scheme

RESULTS

The simulation result for the 4-pump digital system is presented in the following figures.
The directional control valves are ordered at an interval of 4 seconds. After the maximum capacity of the pumping system is dyed, the direction of movement of the hydraulic cylinder is reversed, using the 4/2 electrohydraulic directional valve.
For the DHPS system, as one can see from the figure below, a discrete flow adjustment in 15 points is obtained.

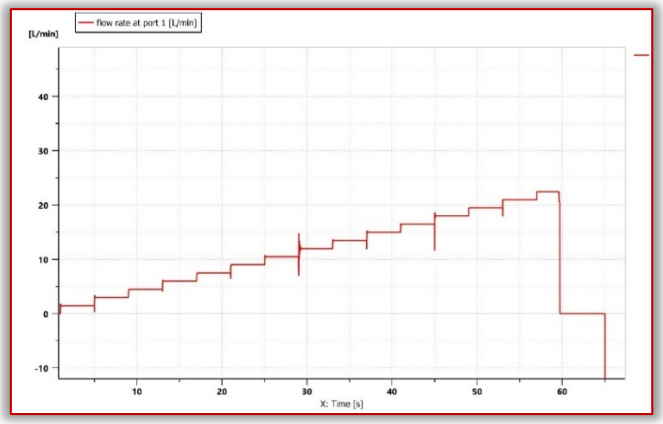


Figure 9 – Pressure and flow at the inlet to the hydraulic motor for the DHPS system

Following the simulation of the DFCU system with five binary coded distributors, a flow variation in 31 discrete points is obtained, as shown in table 3

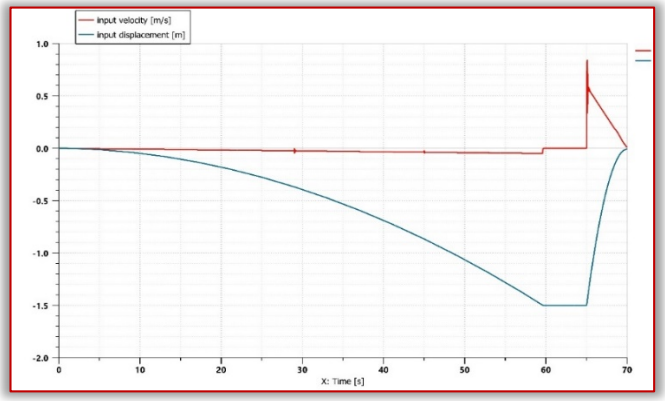
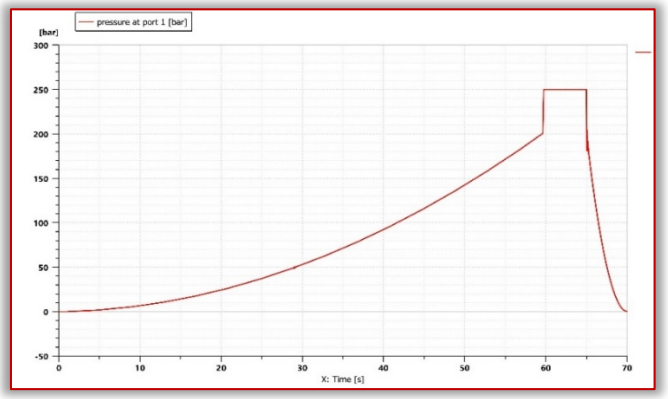


Figure 10 - Input velocity and displacement for the DHPS system



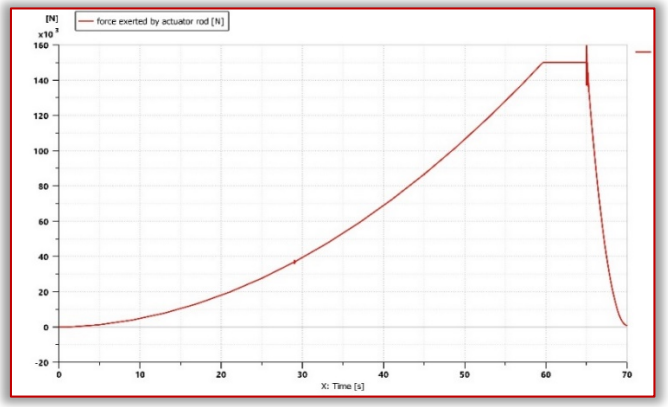


Figure 11 – Hydraulic cylinder pressure and force on the rod for the DHPS system.

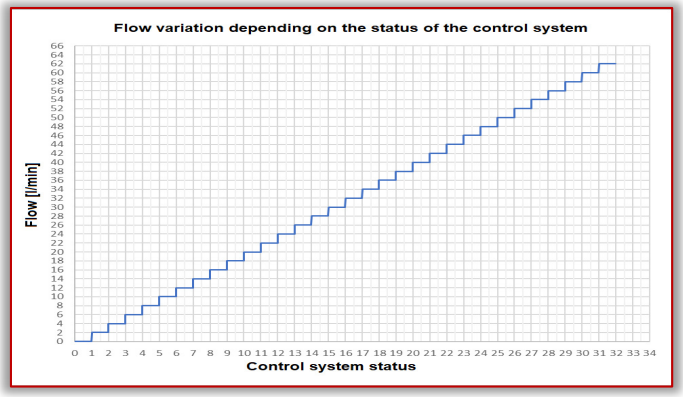


Figure 12 - Variation of the system depending on the status of the control system for the DFCU system

CONCLUSIONS

DHPS and DFCU systems are two systems that use simple components that can be easily replaced and with reduced working fluid requirements.

By using the two systems, discrete flow adjustments are obtained with lower energy losses than in the case of proportional or servo devices, where the flow in addition to the system requirements is sent to the tank through the high-pressure valve.

The world trends are to develop these simple and efficient systems as widely as possible, which makes the subject of ascending interest.

The two digital systems presented above are developed within INOE 2000-IHP and are part of the doctoral theses of two of the authors, therefore based on these results we will move to the next stage that will be the realization of these two digital hydraulic systems and subjecting them to various tests.

Note: This paper was presented at ISB–INMA TEH' 2021 – International Symposium, organized by University "POLITEHNICA" of Bucuresti, Faculty of Biotechnical Systems Engineering, National Institute for Research-Development of Machines and Installations designed for Agriculture and Food Industry (INMA Bucuresti), National Research & Development Institute for Food Bioresources (IBA Bucuresti), University of Agronomic Sciences and Veterinary Medicine of Bucuresti (UASVMB), Research-Development Institute for Plant Protection – (ICDPP Bucuresti), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and Romanian Agricultural Mechanical Engineers Society (SIMAR), in Bucuresti, ROMANIA, in 29 October, 2021

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[1.]Gheorghe STROESCU, [1.]Anişoara PĂUN, [1.]George BUNDUCHI, [1.]Andrei DUMITRAŞCU,
[1.]Mihai OLAN, [1.]Mariana EPURE, [1.]Iulian DUMITRU, [1.]Mario CRISTEA

HEMP CULTIVATION IN ROMANIA. PRESENT AND FUTURE

[1.]National Institute of Research – Development for Machines and Installations Designed to Agriculture and Food Industry – INMA, Bucuresti, ROMANIA

Abstract: Hemp is not a crop prohibited or restricted by law, only that such a plantation must be authorized and monitored by the Ministry of Health, the Ministry of Internal Affairs and the Ministry of Agriculture and Rural Development. Beyond the impediment to authorization and monitoring, hemp cultivation brings more than profitable gains to those who invest in it. It is grown for its relatively high natural fiber content and for its seeds rich in drying oil. Hemp fibers are longer than flax, very durable and quite resistant. They are used to make a wide range of rot-resistant textiles, even in water. Short fibers (tows) are used in the manufacture of mattresses as well as as an insulating material. Lately, the market demand for green hemp inflorescence has increased. The paper will present the partial results obtained in a research project in which a piece of equipment for harvesting green hemp stems was grounded and made in order to process these stems to obtain fibers. However, there are factors in the agro-industrial chain that limit the large-scale marketing of these crops and their products. From an agronomic point of view, some of the problems are associated with technological gaps in harvesting technologies, which prevent the full exploitation of some crops. For example, the production of high-quality textile fibers depends primarily on the quality of the raw material, which in turn is linked, inter alia, to the efficiency of the harvesting system adopted. In most cases, these systems have been developed locally, based on available solutions related to specific local agricultural practice. The purpose of this paper is to present a review of existing mechanical harvesting systems for hemp fiber crops with special reference to hemp. In addition, the paper will provide a description of the innovations that have been adopted in recent years to improve harvesting processes to increase the value of these crops and their products, made by INMA Bucharest.

Keywords: green hemp stalks, industrial plant, technology, processing

INTRODUCTION

Agriculture is the branch of the economy that provides in addition to daily food and a part of the raw material related to other areas of the economy, raw material resulting from the cultivation of some technical plants: flax, hemp, cotton, etc. At the moment, the demand for hemp on the European market is growing, and the value of the subsidies offered by the European Community helps farmers to make a profit.

Industrial hemp (Cannabis sativa) is considered to be one of the most profitable crops. According to specialists, the profit that can be obtained per hectare when cultivating this crop can reach 7-10 thousand euros, but the restrictions imposed by the authorities do not allow farmers to cultivate it.

Hemp is a multifunctional crop that, worldwide in the last decade, has been the subject of many research projects and industrial enterprises (*Amaducci S., et al, 2017)*. Hemp cultivation can reduce deforestation. One hectare of hemp is the equivalent of four hectares of forest, when we talk about the pulp used to produce paper. The wood produced per hectare of hemp is equivalent to the amount of wood that is made by the annual growth of one hectare of mature fir forest. The vegetation period of hemp is about 100 days, which does not compare with the time required to plant and obtain cellulose from the trees of a forest. Starting in 2020, it is expected that most textile companies in the world will switch to the production of hemp fiber.

Hemp strains from local populations and wild hemp contain 10-12% fiber, and improved varieties, 26-32% (*Nedelcu A. et al, 2020*).

Before 1989 in Romania over 50,000 hectares were cultivated with hemp, but in the 2000s hemp disappeared from Romanian agriculture, only after 2012 the cultivation of hemp began to enter the attention of Romanian farmers *(Cotuna O.. et al, 2020)*. Romania was the third largest producer of hemp fiber worldwide, the production being mainly concentrated in the counties of Timiş, Arad, Bihor, Satu Mare, favorable to hemp cultivation. In recent years, trends have been reported to revive hemp into other production niches, such as the production of oil from hemp seeds and the extraction of hemp fibers by mechanical peeling of the stems. Industrial hemp is a plant used to obtain textile fibers for food purposes which, in order to be planted, must by law have an overall THC content between 0.2% and 0.6%. The substance content with psychoactive effects tetrahydrocannabinol (THC) in Cannabis Sativa (industrial hemp) is only 0.2%, ie one hundred times less than in narcotic hemp (Cannabis Indica) (*Carmen Brăcăcescu et al, 2019*). It is time for hemp cultivation to return to the range of agricultural crops in Romania, say researchers from the Lovrin Agricultural Research and Development Station (*Cotuna O.. et al, 2020*).

At Lovrin, the hemp culture never disappeared and the improvement works continued after 1989. At SCDA Lovrin, valuable varieties of hemp have been obtained over time. We mention here the dioecious hemp varieties for fiber and seed: Lovrin 110, Silvana, Armanca and Teodora. Also at the SCDA Secuieni resort, valuable varieties of hemp were obtained. Of particular interest worldwide is the cultivation of hemp for the extraction of cannabidiol (CBD) for the pharmaceutical industry. In this sense, breeders have produced hemp varieties that produce compounds that can have pharmaceutical value. One such product is cannabidiol.

About cannabidiol, studies show that it has antiemetic, neuroprotective, antiepileptic, antipsychotic, anti-inflammatory properties, etc. (*Grotenheim and Müller - Vahl, 2016*). Romanian varieties are not drugs. They have a TCH (tetrahydrocannabinol) content below 0.2%, a level imposed by the EU.

The project developed by INMA *(PN 19 10 01 03, INMA)* aims to achieve technologies and equipment for green harvesting and processing of hemp stalks, to meet the requirements of current growers and processors of hemp cultivation.

MATERIALS AND METHODS

The primary processing of hemp aims at extracting the textile fibers contained in the stems of these plants, by removing with the help of physical, chemical, biochemical and mechanical means the non-filable components (epidermis, parenchyma and lumen) contained in the stems. After processing, two categories of fibers are obtained, which are called *molten fibers* and *unmelted fibers* (*Cuzic-Zvonaru C. et al, 2002*).

Figure 1 shows the complete technological scheme of the hemp processing process in the case of molten fibers. It should be noted that at the moment there are only two smelters in the country.

The molten fibers are obtained, as a rule, by going through two stages:

- in the first stage the aim is to destroy, or at least weaken the connection between the fibrous bundles and the neighboring tissues or the tissues in which the fibers are embedded. This step is called generic melting and is performed by biochemical, chemical or physical means;
- the second stage, performed with mechanical means, aims to eliminate the non-filable parts, respectively the remains of the epidermis and parenchyma, as well as the entire wooden part.

The unmelted fibers, obtained by the so-called "green" processing of hemp, go through a single stage, aiming only at the elimination of the main wood mass of the plants by mechanical processing. The dehulling of the green stems results in a semi-finished product, which is subsequently dried and can be subjected to a ennobling process, biological, chemical or physical, and the fibrous material obtained can be spun directly in this state, even being called green processed fiber. In general, a number of technological phases are included for the primary processing of hemp, some of which are excluded, depending on the variant of obtaining the melted or unmelted fibers.

A complete process of primary processing involves the following technological phases:

- preparation of stems for melting;
- melting the stems;
- drying the molten stems;
- mechanical processing of molten stems by crushing and melting;
- processing and sorting of melita tow by drying, shaking and ennobling;
- sorting flax and hemp;
- pressing and packing the rope or tow.

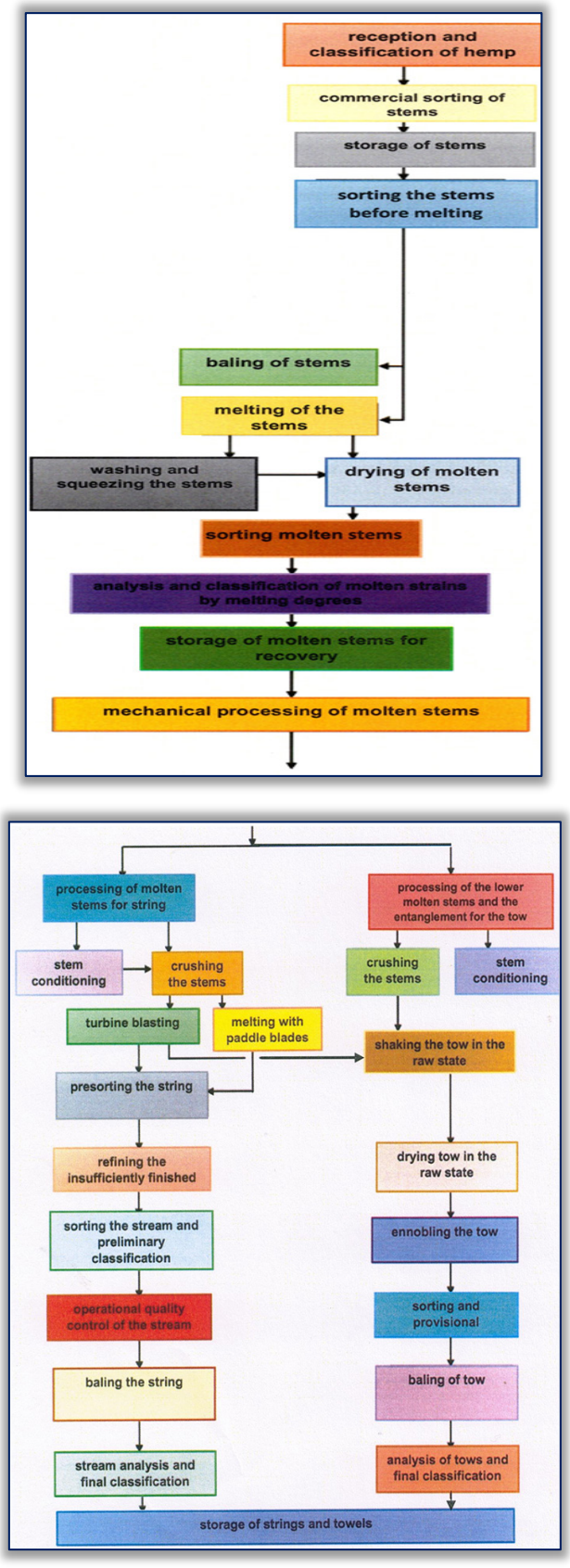

Figure 1. Complete technological scheme of the hemp processing process in the case of molten fibers

If melting is excluded, the resulting fiber being unitary, from the seven phases are excluded those concerning melting and, respectively, the grouping of technical fibers into strings and tow.

Because in Romania the processing of hemp by melting is almost non-existent and to meet the requirements of the beneficiaries, who grow or process hemp, INMA has developed a technology, figure 2 (*Păun A. et al, 2020*) and a technical equipment for harvesting and processing strains of green hemp figure 3 a and b (*Olan M., et al, 2020*).

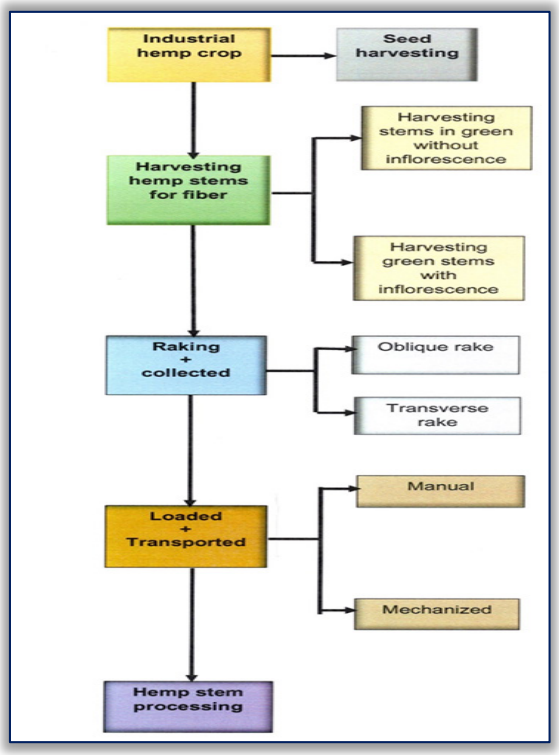

Figure 2. Technology for harvesting green hemp

Figure 3. Technical equipment to process green hemp stalks

The experimental model of Green Hemp Stem Harvesting Equipment ERCV, figure 3 a is intended for the sequential harvesting of hemp stalks, in order to process them to obtain the string.

In the case of using this equipment, the cut plants remain mixed in the furrow, the inflorescence with the stems. Strain losses to be less than 5%; broken stems of up to 6%. It should be noted that this equipment is intended for small and medium farms that grow hemp.

The green harvesting equipment of hemp stems, figure 4 a and b consists of the following components:

Figure 4. a Green harvesting equipment for ERCV hemp stems (Păun A. et al, 2019)
1-ERCV assembled mobile platform - 1.0; 2-Knife 1 ERCV - 2.0; 3- Knife 2 ERCV - 3.0; 4-ERCV hydraulic installation - 4.0

Because the height of the inflorescence of the hemp varieties varies, Knife 2 ERCV - 3.0 has the possibility to adjust the cutting height in a wide range of values with the help of a vertical cylinder. The second hydraulic cylinder works at the stroke ends in the working or transport position of the equipment.

In transport, this knife can be folded 90 degrees backwards on a support (figure 4), with the help of the hydraulic installation. This knife is a double-edged knife like the first knife.

Each knife is driven by a hydraulic motor through a distributor, driven by the hydraulic installation of the equipment.

RESULTS

Before entering the hemp crop, the tractor is started and the two cutting devices are operated by means of the hydraulic installation - ERCV - 4.0, figure 5 (*Bogdanof C-ti.G. Et.al. 2019*).

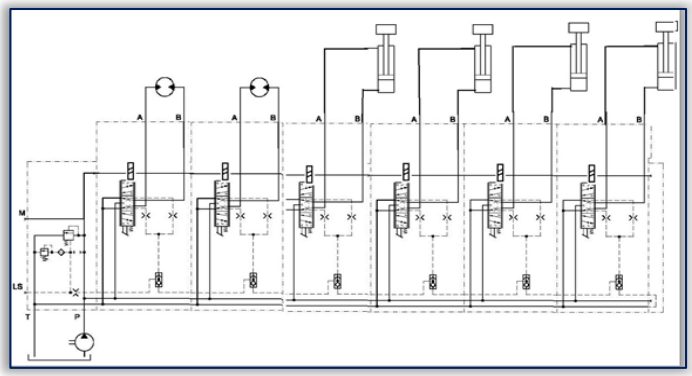

Figure 5. Hydraulic scheme

The equipment for harvesting and processing the hemp stalks in green was subjected to house tests using as raw

material hemp from the culture at INMA. The house tests consisted in checking the following aspects of the standard - SR EN ISO 12100: 2011 - Safety of machines. General design principles. Risk assessment and risk reduction applicable to products. Also, during the house tests, the integrity of the equipment and the general technical condition of the transmission, the guards, the active organs were checked.

The experimental ERCV model provides the following general characteristics:

- car type: Trailed
- energy source: tractor >65 CP
- type of the cutting device: double knife
- number of cutting knives: 2
- rear cutting device: 100 mm
- front cutting device: 1500-2500mm

As the 2021 hemp crop (from INMA) did not meet the requirements imposed by the harvesting equipment (uneven height, low density, etc.) the tests under operating conditions are to be carried out in 2022.

CONCLUSIONS

It is a technical equipment for small and medium-sized hemp farms. From the house tests it was found the following:

- the average cutting height from the ground did not exceed 100 mm;
- due to the variable height of the culture not all the inflorescences were cut, a compact furrow did not result
- strain losses were greater than 5%;

It is a technical equipment for small and medium-sized hemp farms.

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