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Also, the **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XIV [2021], Fascicule 3 [July – September]**, includes scientific papers presented in the sections of:

- **ISB–INMA TEH' 2020 – International Symposium (Agricultural and Mechanical Engineering)**, 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, 30 October, 2020. The current identification numbers of the selected papers are the **#3, #5, #7, #9, #13, #18** and **#19**, according to the present contents list.
- **IIZS 2020 – X International Conference on Industrial Engineering and Environmental Protection**, organized by Department of Mechanical Engineering, Department of Environmental Protection and Department of Industrial Engineering in Exploitation of Oil and Gas, Technical Faculty Mihajlo Pupin Zrenjanin, University of Novi Sad (SERBIA), in cooperation with partners University Politehnica Timisoara, Faculty of Engineering, Hunedoara (ROMANIA), University St. Kliment Ohridski, Technical Faculty, Bitola (MACEDONIA), Aurel Vlaicu University of Arad, Faculty of Engineering, Arad (ROMANIA), University of East Sarajevo, Faculty of Mechanical Engineering East Sarajevo (BOSNIA & HERZEGOVINA) and University of Giresun, Faculty of Engineering, Giresun (TURKEY), in Zrenjanin, SERBIA, in 08–09 October, 2020. The current identification numbers of the selected papers are the **#4, #8, #12** and **#15,** according to the present contents list.

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[1.]Rajab GHABOUR, [2.]Péter KORZENSZKY

TECHNICAL AND NON-TECHNICAL DIFFICULTIES IN SOLAR HEAT FOR INDUSTRIAL PROCESS

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Abstract: Despite of the tremendous potential in domestic, household, and industrial sector, the solar heat contribution is generally neglected in many academic and institutional projects. Thus, decision makers in many countries have paid lesser attention to solar thermal energy compared to other renewable energy solutions. Also, there is uneven level of solar thermal application in countries with similar climate and energy conditions which highlights the importance of creating public policies to go over the reasons. Nevertheless, solar thermal energy can provide a noticeable portion of the mankind energy demand which half of it is in heat form. Solar thermal technologies can be passive or active, for cooling or heating however, but still facing numerous obstruct which pursuing the dissemination of these technologies. Most of the technical difficulties have been solved with some technical limitations, while economic difficulties still counter high investment and upfront costs, legal difficulties of being permitted, and other difficulties such as lack of awareness among customers and policy makers, and insufficient training of professional, installers and designers. In this paper, an attempt to present an analysis of the barriers facing the solar integration in the industrial market from different aspects (technical, economical and others). In addition to the up-to-date solution for each problem.
Keywords: solar thermal, industrial processes, energy storage, technical barriers

INTRODUCTION

Solar heating for industrial process considered as one of the cleanest renewable energy solutions in many countries and under several climate conditions. Where a significant share of the final energy consumption is dedicated for low and medium temperatures (below 250°C) in the industrial sector. Those industrial activities have a tremendous impact on the country's economic growth, and it has 35% share of the world's growth [1]. This share can be higher in developed and growing economies such as USA 33% [2], Germany 28% [3], India 47% [4] and China 70% [5] but it depends on the level of the industrial activities in the country. Industrial sector consumes the needed demand in either electrical or thermal energy form. Where electrical portion is used for operating the electrical elements such as motors, lights, and air conditioning, while thermal energy is used for heat processes such as drying, dyeing, bleaching, etc. So that, a substantial share of the industrial energy demand is for industrial processes. However, this share varies with the industries, process type, and the manufactured products. Various industries such like textile, food, milk, beverage, pulp and paper, chemical and pharmaceutical, automobile, leather and rubber, etc., including several processes such as pressing, distillation, evaporation, pre-tanning, etc., all those processes need considerable temperature requirements that can be afforded by solar thermal system. According to those industries, a major fraction (around 60%) of the thermal energy demand is reportedly in the temperature range of 30-250°C [6].

All heat needed for processes in industry are generated typically by a heating device that generates heat then it is transferred from the source of production to the end use by a transferring mechanism which works as a distribution system. Heat process is carried out directly when the generated heat within the material itself, or indirectly where the heat is transferred by heat transfer mechanisms such as conduction, convection and radiation and this system often involves a boiler or a furnace. The example of the direct mode such as hardening and tempering, while drying and washing are examples for the indirect mode [7].

Process heating systems typically are two types: combustion-based, or electricity based. The heat is produced in the combustion-based systems by combustion of solid, liquid, or gas fuels, and then transferred directly or indirectly to the heat process. Examples of combustion-based heating systems include furnaces, ovens, and steam boilers. While the heat is produced in electricity-based heating systems by means of electrical current or electromagnetic field. Examples of electricity-based heating systems include microwave processing and infrared emitters [8].

Heat transfer media and fuels used in industrial process heating systems vary across regions and countries according to the availability of the fuels. Globally, the use of coal and liquid fuels accounts for about half of the total share of fuels used in the industrial sector. In 2020, 27%, 22%, 28.4%, 16% and only 6.6% are the shares of the liquid fuels, natural gas, coal, electricity, and renewable energy sources (solar and biomass) respectively [9]. In oil importing countries where the industrial sector demand is increasing, it would be a direct relevance to harness solar energy for not only meeting the process heating demand, but also to reduce the greenhouse gas emissions. So, it can be associated with the environmental benefits. On the other hand, the use of the heat transfer medium depends on the process and the end use requirements because the heat medium may or may not have a direct contact with the under-manufacturing

product. So that, the desirable characteristics of the heat transfer medium that can be used in industry are high heat capacity, low vapor pressure, low viscosity, low corrosiveness, and high thermal stability [10]–[12].

Steam is the most used heat transfer medium in the industries which accounts for 37% and 33% in the USA and UK respectively [13]. The reason beyond it, that it has a high energy density compared to hot water and thermal oils, it can be stored in large quantities, and it can be transferred at constant temperature. Therefore, it accounts for a significant amount of the used energy in in the industrial sector. For example, the fuel used for generating steam in pulp and paper, chemical manufacturing, and diary are 84%, 47% and 50-60% respectively.

Even though, using hot water as a medium in the industrial processes also have a significant share due to its easy operation and maintain, but it requires a large distribution pipe diameter as compared to steam. Thermal oils are also used in industry due to its capability of operating under low pressures since its evaporation temperature can reach up to 300°C. However, it costs more, and it has lower specific heat capacity than water. Finally, hot air is used in drying applications, tea, and paper manufacturing [14].

Solar energy is one of the most sustainable energy resources and it is promising as an alternative source for thermal applications and power generation in both domestic and industrial sectors [15]-[16]. The thermal conversion of the solar energy can have higher efficiency up to 70% compared to the electrical conversion. Even for power production, the efficiency of the photovoltaic systems have 15-20% system efficiency, compared to 20-25% for thermal systems [17]. Therefore, use of solar thermal energy for industrial processes meets the increased industrial energy demand.

IEA (International Energy Agency) has established the solar heating and cooling program (SHC) back in 1977 to promote all the aspects of solar thermal energy utilization. These collaborative activities involve experts from Europe union and IEA member countries. For example, Task 33 (conducted between 2003 to 2007) showed the huge potential for using heat in industry and the importance of opening a new market sector to integrate solar thermal systems into the industrial processes. This integration requires further improvement and development of the solar thermal system's components to fulfill the stipulated requirements [6].

Task 49 (conducted between 2012 to 2015) reported that globally 30% of the industrial heat demand is needed at temperature below 100°C, while in the EU27 28% of the overall energy demand is heat below 250°C [18]. In this task 120 operating solar thermal systems are reported worldwide with total capacity of 88 MW_{th} which equals 125,000 m^2. The three main tasks in this project were:

- to optimise the processes and the solar thermal system (e.g., lower the process temperature, control safety issues etc.),
- system optimization (e.g., Pinch analysis), and
- integration of the solar thermal energy based on exergetic considerations.

Finally, Task 64 (started 2020-2023) focuses on process temperatures from above ambient up to 400-500°C aiming to help solar technologies becoming a reliable part of process heat supply systems. The key objective of this task is to promote, identify, and verify the role of solar heating systems in combination with other heat supply technologies (fossil and non-fossil) [19].

Selecting an appropriate solar collector technology for process heat demand in industry usually relays on four factors:

- operating temperatures
- annual solar yield
- solar collector efficiency, and
- costs [20]-[21].

Mainly three different types of solar collector technologies are being utilised in the solar industrial applications – flat-plate (FPC), evacuated tubes (ETC), and concentrators. Usually, water and air are used as heat transfer medium within the collector loops, while sometimes water needs to be mixed with glycol to avoid freezing and burst in case there is a drop down in the ambient temperature below 0°C. Solar air collectors are being used in food processing industry to reduce the heat losses that happen due to using fossil fuel to dry food materials in open air. FPCs and ETCs are used for low temperature industrial applications [22], while solar concentrators can produce process temperatures up to 300°C, which is available in several designs such as parabolic dishes or troughs and linear Fresnel reflector [23].

In the literature, the reported potential of harnessing solar energy in industrial processes are very large, while so far, the actual installed capacity is very small due to several reasons. In this study we are focusing on categorizing these barriers and providing the most up-to-date solutions for eachs case. The reported barriers based on the most recent literatrue are:

- difficulties in itergating solar process heating systems in existing industries
- optimising process heating streams
- lare scale industries are rather lesser in numbers, compared to the majority of the industrial units which requires tailormade solutions for each case study
- high upfront costs for small and medium enterprises (SMEs)
- unavailability of competent, qualified designer and installers
- lack of compact thermal energy storage solutions
- unavailability of adequate regulatory support and policy comapred to photovoltaic and solar thermal genergation solutions.

The present work will focuse on highlighting the most essential reasons in details and to give a solution for each of it.

BARRIERS TO DIFFUSION

Worldwide, industrial process heat accounts for more than two-thirds of the total energy demand in industry, where half of this demand is for heat temperatures below 400°C.

Currently, approximately 41% of the industrial primary energy consumption is covered by petroleum, and approximately 40% by natural gas. Therefore, by 2030 there is an energetic potential to provide around 15 EJ of solar thermal heat which account for 10% of the industrial energy demand. The potential markets for solar thermal systems are typically in the food, textile, transport, machinery, pulp, and paper industries, where approximately 60% of the needed heat temperature is below 250°C. One of the biggest barriers is the structure of the industrial sector.

Concerning large scale industries, which considered as energy-intensive factories, the bottlenecks are the difficult integrating of solar heat into existing process heat streams, and the lack of familiarity with the targeted technology. While for SMEs, which account for 95% of the industrial enterprises, need to be tailor made design to meet with the specific energy demand at specific location and circumstances. For SMEs, the feasibility study of this kind of projects is low, but it is hampered by the high upfront costs. However, the increasing costs and volatility of fossil fuel prices improve the potential of deploying solar thermal technology [17].

— TECHNICAL BARRIERS

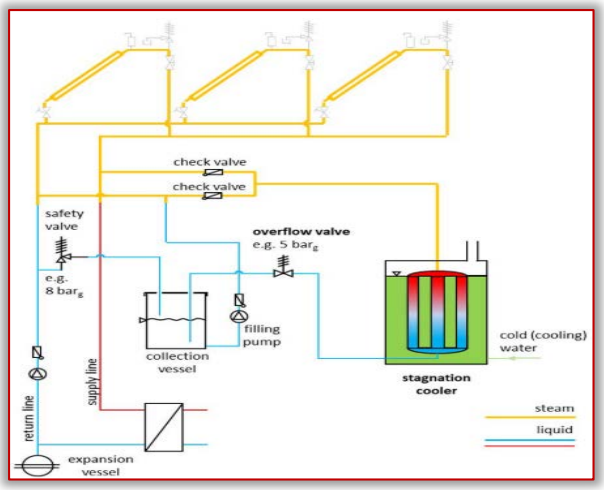
Stagnation handling

Solar heating systems must operate totally reliably in all circumstances and conditions that may happen. Solar thermal applications in general must cope with the phenomenon of stagnation therefore, it requires specific technical solutions. Stagnation describes the case of a solar thermal system where an interruption happens in the flow of the collector loop and more solar radiation is absorbed by the solar thermal collector therefore the fluid in the collector loop is heated up to a temperature where the absorbed energy equals the heat losses. In low temperature applications, stagnation considered as a reliability issue so that, the use of solar thermal energy in medium-to-high temperature applications (mainly solar concentrator technology) require further importance of stagnation/ overheating prevention strategies.

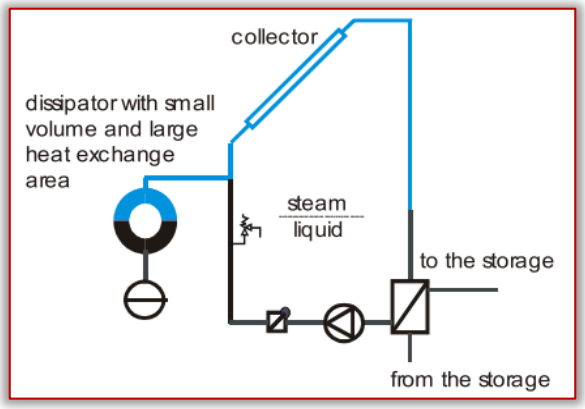
In comparison to conventional heating technologies, the solar thermal system cannot be simply shut down to prevent any extra heating in case of technical defects, lack of heat demand, or power blackout. Different effects during regular operating conditions have to be avoided depending on the solar collector concept such as preventing the heat transfer medium being released to the atmosphere in case of high-pressure state, as well as preventing too high temperatures that may damage the solar collector parts or the solar collector loop. For small to medium scale residential solar thermal systems typically, pressure release valve can be replaced by expansion vessels or simple heat dissipaters mounted in the collector loop [24]. While for industrial applications designed for higher supply temperatures with more efficient solar thermal collectors, other strategies should be applied such as active cooling devices for de-focusing (in case of tracking system) or overheating prevention. This solution guarantees a long term, low-maintenance, reliable operating conditions.

If the stagnation is an accepted operating mode in the process heat, extra measures must be added to prevent the solar loop components from being severely damaged by the high pressure or temperatures caused by stagnation.

As a solution for the stagnation for small domestic hot water systems, the expansion vessels are the state of the art, while for medium-scale solar systems inexpensive simple aluminium finned-tube heat exchanger can significantly reduce the steam in the primary loop as in Figure 1a. This solution can dissipate around 750-1000 W/m. If this solution is not sufficient to protect the temperature-sensitive components from steam, then passive evaporative air coolers can dissipate higher energy with small surface heat exchanger as in Figure 1b. The big advantage of this system that it can work independently of the electrical supply.



(a)



(b)

Figure 1.(a) Evaporative cooler (b) Passive heat disspators [24]

Overheating prevention

As soon the operation temperature is exceeded in solar thermal system, the overheating occurs as in Figure 2. It could happen for several reasons such as: if the energy delivered by the solar collectors exceeds the heat demand and the storage capacity, or if there is a failure in the controlling system. If there are no precautions, the collectors or the whole collector loop will be damaged, or it will reach to stagnation temperature. So that, the collector loop components must be chosen carefully to meet the operating conditions.

In case if stagnation is not an accepted operating mode in the process heat, then overheating prevention is a must to

prevent the solar thermal system from temperatures and pressure stress caused by stagnation.
The stagnation temperature occurs when the thermal energy output of the solar thermal collector $\dot{Q}_{coll}$ drops to zero where $\dot{Q}_{coll}$ is represented by the following equation:

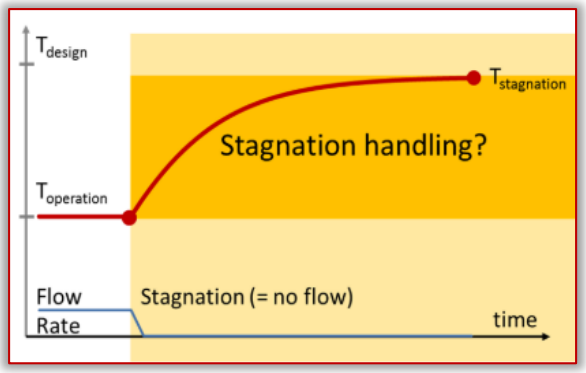
$$\dot{Q}_{coll} = A.G.(\eta_0 - a_1.\frac{(T_{m,f}-T_a)}{G} - a_2.\frac{(T_{m,f}-T_a)^2}{G}) \quad (1)$$

where:

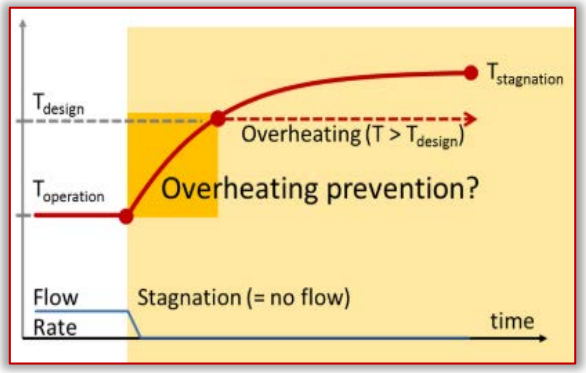
$\dot{Q}_{coll}$	Thermal output of the collector	[W]
A	Collector area	[m^2]
η_0	Conversion factor (peak efficiency)	[%]
a_1, a_2	Heat transfer coefficients	[$Wm^{-2}k^{-2}$]
$T_{m,f}$	Mean fluid collector temperature	[°C]
T_a	Ambient temperature	[°C]
G	Solar irradiance on collector plane	[Wm^{-2}]

The stagnation temperature is reached when $\eta_0 = 0$ and the $T_{m,f} = T_{stg}$:

$$T_{stg} = \frac{\sqrt{G.\eta_0.a_2+(\frac{a_1}{2})^2}-a_1}{a_2} + T_a \quad (2)$$



(a)



(b)

Figure 2. Temperature over time of stagnation in case of (a) $T_{design} > T_{stagnation}$ (b) $T_{design} < T_{stagnation}$ [24]

To prevent overheating, the concept always has to address the lowest design temperature of all the parts of the collector loop. For a parabolic trough collector, overheating will have different causes and effects. Because during the overheating process the cooling system and the absorber tubes will be affected based on the design temperature. In general, the affected parts are as in Table 1.

Table 1. Overheating effect on system components

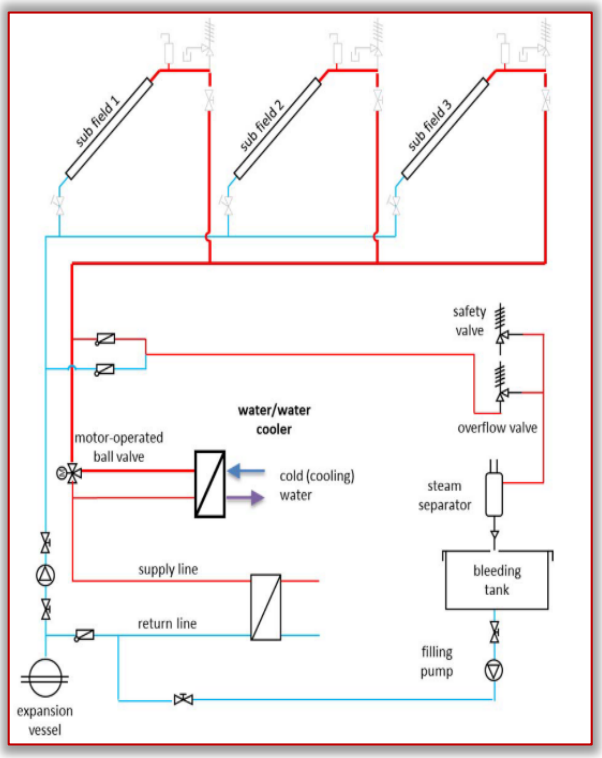
The component	The effect
The pumping system	Non-metallic components and rubber seals will be damaged
The absorber	The coating will start to degenerate
Collector tubes	Permanent deformation may occur
Thermal oil	Oil may lose its efficiency
The piping system	Rubber seals will crumble, and leaks appear in the system

As a solution for the overheating and the stagnation, in industrial-scale solar systems, every closed circuit filled with heat transfer medium is equipped with expansion valves which are able to absorb the expansion of the medium in case there is a temperature increase. Moreover, a safety valve which is pressure controlled is obligatory in all scenarios, that opens in case when the defined maximum operating pressure is reached and then release the evaporated transfer fluid. In this case, the opened valves lead to a partial emptying of the loop from the heat transfer fluid, this causes addition costs and maintenance. While in small-scale systems (such as domestic hot water), the expansion vessels are designed to absorb both the collector fluid expansion and the vaporized fluid. This means larger vessels, thus costs more.
In large-scale solar systems, such as district heating system, it is designed in a way that there is a constant base heat demand that the solar heat supply does not exceed. In this case, the stagnation occurs only by a power outage or a technical malfunction which means rarely to happen. While in industrial-scales, stagnation happens more frequently due to company holidays, process dependencies and weekend shutdowns therefore, low maintenance is inviable and overheating prevention and stagnation handling must be guaranteed.
The strategies developed to manage the stagnation and the expansion are either to design the system similarly to conventional small-scale systems which are able to cope with steam (stagnation handling), or to avoid the evaporation of the heat transfer medium (overheating prevention).
To prevent overheating there are different embedded protections in the collector concept, it is divided into three main categories:

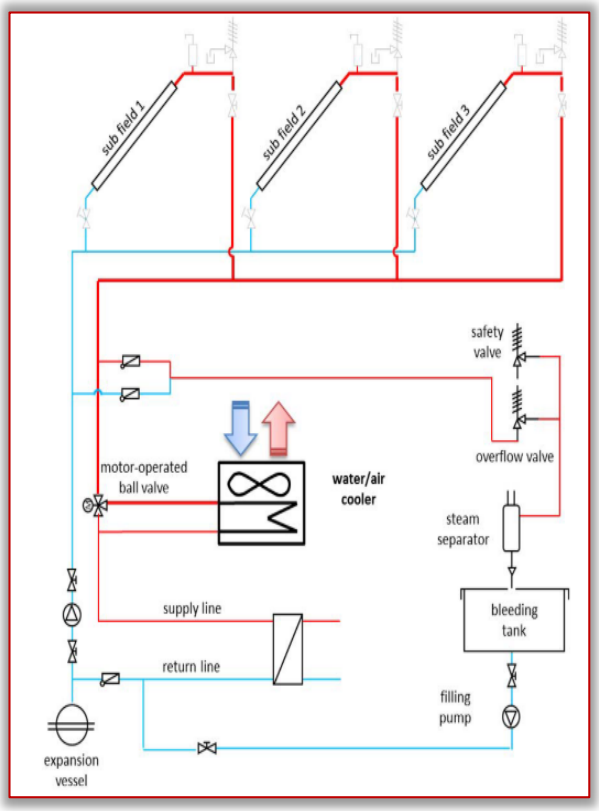
- mechanically embedded systems such as flaps or heat dissipating methods
- material embedded such as thermo-tropic coating works as absorber and
- proper designed heat pipes.

If the emptying behaviour is unfavorable conditions on the system or collector level, active re-cooling devices should be used to prevent overheating in the system components (e.g., valves, pumps, membrane, etc.). In case of stagnation and overheating happens due to lack of heat demand in the solar process heat applications, which is the most critical issue, this solution is very efficient and reliable.
However, it depends on electricity so it will not function during outages in case there is no emergency power supply.

Or an additional safety valve can be mounted which may cause a partial emptying of the loop. There are two main types of it: water/water heat exchanger, or water/air heat exchanger [25] as in Figure 3.



(a)



(b)

Figure 3. Active cooler in the solar primary loop
(a) water/water (b) water/air

Another solution to avoid steam generation is to full drain the system at pre-defined temperature. When the heat supply from the collector cannot be used or stored or when the supply heat from the solar collector field is not sufficient, the solar loop pump stops and then the entire collector field is automatically drained to a drain-back tank as in Figure 4. When the solar irradiation is again sufficient, the solar pumps switched on and the collector loop is filled again with water so that the normal process starts in a few minutes. This system has a big advantage since it uses only water as a heat transfer fluid, therefore there is no ageing or maintenance which was associated with glycol-filled circuits. This system is a simple and reliable design with much experience in the small and medium systems and limited practical experience with the large-scale systems. In cold climates where there is a potential of frost, this can be a special challenge for this system.

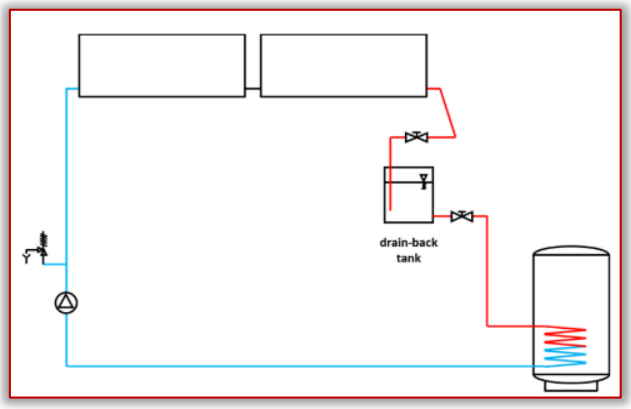


Figure 4. Drain-back system

In case of concentrating and tracking collectors, the defocusing is the easiest solution to prevent both overheating and stagnation. This occurs due to moving the receiver out of the beam radiation using an algorithm implemented in a programmable logic controller (PLC) which controls the movement of the collector. It works when the mass flow of the heat fluid stops or when a specific temperature is reached, the collector moves to a new position where less solar radiation is absorbed, therefore the temperature will decrease, and no overheating is produced.

Night cooling is a hydraulic concept that enables the solar thermal storage tank to unload during the night hours. In case there is no heat demand is needed in the upcoming days or the storage tank is fully loaded, the solar heat generated during the daytime can be dissipated during the night by circulating the hot water from the top of the tank through the entire solar collector field (only applicable for FPCs), therefore it operates like a large radiator during the nighttime.

The efficiency of the night cooling depends on the efficiency of the solar collector field, the temperature of the thermal fluid, and the ambient conditions (wind speed, temperature, and cloudiness). For cold climates such as central Europe, an Austrian brewery Goess uses night cooling to dissipate 80% of the gained solar thermal during the daytime under clear night conditions, while 20-25% during unfavorable conditions (sultry weather, no wind, cloudy).

- **Process integration**

Process integration or Pinch analysis is an engineering filed that seek to reliably produce a product considering the minimum energy inputs. To reduce the economic inefficiencies and optimise the solar collectors, the variability of the energy supply must be quantified based on ambient temperature, daily solar radiation, and available storage opportunities.

If the solar thermal systems designed to provide all the heat demand, the manufacturer must align the production to match the supplied energy, or to store it for later use. One the other hand, solar system can be designed to supply a portion of the total required energy and the rest can be fulfilled by a complementary source. For the available commercial low-temperature solar collectors, it can be an effective solution for pre-heating purposes.

- **Energy storage options**

Large-scale thermal energy storages are a budding market, but it can compensate the absence of the sunlight. For low and medium temperatures (up to 250°C) the storing medium can be a heat transfer fluid such as hot water or oil. Wile for high temperatures, storing the heat becomes more difficult, requires alternative mediums and storing material, and more costly.

The only practical solution for high temperatures is molten nitrate salt (220 to 565°C) which has proven its reliability at commercial scales. Nevertheless, the national renewable energy laboratory (NREL) develops heat transfer fluid that sustain and operate at temperature 0 to 1300°C. This is a step forward since the thermal loss from the heat storage tank was up to five times greater than originally expected during the 70s and 80s.

— NON-TECHNICAL BARRIERS

- **Cost**

The economic viability of a solar thermal system depends significantly on two main factors:

≡ the initial cost of the installation and

≡ the prices of the alternatives.

High upfront payments usually prevent industrial companies from investing in new technologies, even if the long-term lifetime costs would be lower. Nevertheless, the costs for solar thermal systems are decreasing annually, and the financial investment in solar technology are more stable than many types of fossil fuels. Due to this, the biggest driver of the solar thermal systems is the prices of the alternatives such as coal, natural gas and oil. As the prices of these alternatives fluctuate and become more expensive, as it is easier to justify the investment in solar technology. Due to the high volatility of fossil fuel, some manufacturers accept to have high upfront costs with a predictable payback period.

The solar thermal system can be more cost effective when it is tailored to the specific case study of the plant. On the factory level, large-scale system can benefit from the scale economies to lower the investment costs, leading to increase the viability of the project. While on the national level, when the installed capacity gets doubled, the estimated costs can be reduced by approximately 20%.

Here governments play a major role by applying subsidies which will not only reduce the upfront costs, but also strengthen the willingness of householders and enterprises tending towards solar which has been proven that it works properly, in addition to its attribution of a public good. Besides the direct increasing of energy security and reducing greenhouse emissions, subsidies accelerate the cost reduction of growing climate friendly technologies by learning by doing process and the deployment of the early market stage. It should be noted that "stop-and-go" polices have proven a disastrous result of emerging market, since the support was not long enough to create a difference in the costs.

Thus, if there is no long-term strategies or goals for deploying solar thermal technologies, governments and industry have no way to estimate the progress and the chart path which lead to a sustainable, and mature solar thermal market.

- **Variability**

Renewable solution like wind and solar energy can be predicted at a high degree of confidence. In industries that require 24/7 demand, the availability of solar energy can lead to a serious challenge [26]. The reliability of the supplied heat from the solar thermal system is a paramount concern to several industries, where an unanticipated disruption in the supply demand can lead to an economically devastating. Solar thermal technology is a reliable solution but not always available therefore, it can be a good solution for industries that do not require a constant production, or for whom the available radiation creates a good matching with the heating requirements. On the other hand, solar thermal collectors have an annual output for less than 1000 working hours, more likely to be 500-700 hours, compared to photovoltaic (PV) and concentrated solar power (CSP) for 1000 and 2000-2500 hours, respectively. It is serious also when the demand is low or zero during summertime, while the supply at its peak, in this scenario solar thermal systems are not suitable solution.

- **Legal and behavioural barriers**

Split incentives are one of the most important barriers which arise for solar thermal technology both in rental and new construction markets. Building's owners and property developers have little incentive to invest in solar thermal solution while renting their properties since the return of investment will go to the occupants. In theory it can be solved by making a financial arrangement between the landlord and the tenant so they can share the benefit. While in practice it is harder to solve due to the high transaction costs and the market inertia.

Other scenarios happen in large companies where decision makers think that they may not benefit from the savings resulting from the installation of solar thermal system. While in existing collective dwellings if the owner has his own system, it will be hard decision to modify the installation for solar heat and probably it still requires

permitting from the other owners since they have only one roof.

Therefore, experts consider solar thermal technologies for dwellings generally possible only in new constructions.

Legal barriers vary from country to country, where following national or local regulations, ground mounted, or roof mounted installation will require permits. There are consequences of having a permit request such as procuracy procedures and costs for the application and the lawyers.

CONCLUSIONS

For several industrial sectors such as textile, metals and plastics, paper and pulp, chemicals, food processing etc., the share of thermal energy demand for various processes such as drying, cleaning, distillation, blanching, pasteurising, sterilising, cooking, surface treatment etc., it can be efficiently provided by solar thermal collectors due to its low and medium temperature range. There is a tremendous potential of adopting solar heat for industrial processes in most of the countries worldwide. The potential of implementing solar heat in European industry estimated at approximately 260 PJ which corresponds 143-180 million m^2 of collector area. However, the disseminated and reported levels are relatively low due to several barriers representing the large gap between the potential and the installed capacity.

In this paper we discussed the most important barriers technically such as the overheating and the stagnation and non-technically such as the upfront costs particularly in SMEs, and the lack of subsidies and appropriate promotional initiatives. Contemporary solar collectors for providing solar heat are available in the market such as FPC and ETC that can provide low temperatures, while several solar concentrating technologies (such as linear Fresnel reflector, parabolic trough, etc.) can produce an intermediate temperature reaches up to 300°C. Also, we discussed the solution for each barrier.

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CHARACTERIZATION AND EVALUATION OF MAHOGANY (*KHAYA IVORENSIS*) DUST-EGG SHELL-EPOXY COMPOSITES

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Abstract: The conversion of bio-agricultural wastes into composite material for engineering applications is a strategy to add more value in waste utilization and help in the composites with epoxy resin and 10 wt.% NaOH treated *Khaya ivorensis* dust and egg shell particles were prepared by open molding technique. Tensile strength, flexural strength and hardness tests were carried out to evaluate the composite mechanical properties. The results showed that the tensile and flexural strengths increase with addition of reinforcement materials. The composite sample with 3 wt.% wood dust and 10 wt.% egg shell particles displayed highest tensile strength of 34.87 MPa, while the composite sample with 10 wt.% wood dust and 10 wt.% egg shell particles have highest flexural strength. Hardness value of the composite increases with addition of reinforcement materials and maximum at 5 wt.% wood dust and 10 wt.% egg shell particles. In addition, water absorption characteristics of the composite increases with increasing percentage of wood dust. Optimum composition of wood dust and egg shell can be used to produce polymer matrix composites with good mechanical properties.

Keywords: Eggshell, *Khaya ivorensis* dust, mechanical properties, composites

INTRODUCTION

In recent time, interest in composite material has been on the increase due to its unique properties compare to other engineering materials. Composite material refers to a multiphase material composed of distinct constituent, known as reinforcement, distributed in a continuous phase known as the matrix, and resulting in a material with properties that are significantly different and not achievable using each constituent on their own. Combination of two or more materials with different properties without blending or dissolving them into each other formed composite materials [1].

Composite materials are significantly used in different major applications, such as in transportation, medical applications, oil and gas, aerospace, construction and infrastructure, energy, marine, recreation and sports, among others. This is due to the advantages they have over other materials in terms of properties like light weight, resistant to corrosion, design flexibility and processing, durability, strength, magnetic properties, and good conductors or insulators of heat [2].

Development of composites using bio-agricultural by-products (like egg shell, wood, etc) makes it possible to achieve materials of good mechanical properties, such as material with equal strengths, both in tension and compression [1,2,3,4]. Development of composites helped to overcome deficiencies in some materials [3]. The use of bio-agricultural wastes (like wood dust and egg shell) in the development of composites helps to achieve materials of low cost, less health risk, comparable specific tensile properties; and with non-irritation to skin, bio-degradability, renewability, and non-abrasive to the equipment [5].

Wood is a natural composite material which finds applications in building constructions, automobile, furniture works etc. Wood dust (saw dust) is a by-product of wood processing which are largely discarded as wastes into the environment. In Nigeria, about 1.8 million tons of wood dust is generated annually [6]. The use of wood dust as a filler in composite material has been increasing over the years for various applications such as in housing, automotive, aerospace etc. [7]. Recycling of wood dust for use as a constituent of composite material would help in reducing environmental pollution and also increase the spectrum of value addition to wood processing by-products.

Chicken eggshell is an important agricultural by-product that causes environmental pollution, most especially in countries where developed egg product industries are located. Annually, eggshells are disposed of in landfills as a waste mostly all over the world [8]. Several attempts have been made to use the chicken eggshell for various applications. Good availability and chemical composition of chicken egg shell make it a worthwhile constituent material in the production of polymer matrix composites [[9].

Environmental problems that are caused by irresponsible disposal of wastes are drastically reduced if agricultural wastes are adequately utilized [10]. Environmental and health quality will be protected by searching for effective and proper way of managing agricultural wastes [10]. Usage of bio-agricultural wastes will help to obtain value added products (such as biomaterial used in medical surgery and therapeutics, and in production of automobile components), a side from environmental protection. To achieve sustainable development, waste utilization is a priority [11].

In this study, characterization of the polymer matrix composite formed from combination of wood dust and egg shell particles reinforced were investigated to ascertain their suitability for engineering applications. This will also help to promote development of polymer matrix composite, a biodegradable material which is highly desirable in many applications of human endeavors.

MATERIALS AND METHODS

— Materials and equipment

Khaya ivorensis dust was sourced locally from a saw mill in Tanke area of Ilorin, Kwara state. The chicken egg shells were sourced from the waste bins of restaurants also in

Tanke area of Ilorin, Kwara State. The collected egg shells were thoroughly washed with fresh water to remove impurities, including the thin membrane. *Khaya ivorensis* dust and egg shell were oven-dried at 80°C for 24 hours to remove the moisture. Dried egg shells were pulverized to obtain egg shell particles using ball milling machine and sieved to 0.5 mm particle size. The elemental compositions of the eggshell were determined through SEM/EDS analysis.

Khaya ivorensis dust was sieved to 1.0 mm particle size. Epoxy resin and hardener were purchased at a chemical store in Lagos. The matrix was prepared by mixing epoxy resin with 2wt.% hardener in line with the practice of Anjali *et al.* [12]. Equipment used are: digital weighing balance, oven, spatula, universal (testometric) testing machine, sieves, mixing bowls, gloves, masking tape, scissors, sodium hydroxide solution (NaOH) and distilled water. Wooden moulds were fabricated at Temitope Furnitures in Tanke area of Ilorin, Kwara State, Nigeria.

— Surface treatment of wood dust and egg shell particles

Surface treatment of wood dust and egg shell particles was carried out by soaking them separately in 10wt.% solution of NaOH for 24 hours at room temperature and stirred thoroughly, after which they were separated with sieve, washed with distilled water and oven dried at 110°C until constant weight was achieved. The treatment with sodium hydroxide is necessary in order to improve interfacial bonding between the matrix and reinforcements and hence, better mechanical properties of the composite [13,14, 15].

— Composites fabrication

Various mixing proportion of wood dust, egg shell particles and epoxy resin, as presented in Table 1, were properly mixed together for a period of 5 minutes to obtain homogeneous mixture of the constituents before pouring into the mould. After pouring, the composites were left in the mould for 24 hours to solidified, then, removed and placed in an oven for 6 hours at 40°C to properly harden and cure.

Table 1: Mixing ratio of wood dust, egg shell particles and epoxy resin

Samples Designation	% of Wood dust (g)	% of Egg shell particles (g)	% of Epoxy resin (g)
A	-	-	100
B	10	-	90
C	10	3	87
D	10	5	85
E	10	10	80
F	3	10	87
G	5	10	85

MECHANICAL TESTS

— Tensile test

The composite samples' tensile strengths were determined according to ASTM D638 standards [16] using Computerized Testometric Testing Machine (Model No 0500-10080, Win test analysis; 100 KN capacity, England made). Each test sample was tightly held between the two grips of the testing machine and a progressively increasing load was applied on the test sample at a constant rate of 2 mm/minute. As the load increased, deformation readings were automatically recorded until rupture of the sample occurred. Three samples of each composite composition were used for the test and the average values were recorded.

— Flexural test

The composites flexural strengths were determined in accordance with the guidelines in ASTM D790 standards [17] using Computerized Testometric Testing Machine. Three point bend flexural test method was used. The machine applied a progressively increasing load on the composite at a constant rate of 2 mm/minute until it fractured. Three samples of each composite composition were used for the test and the average values were recorded.

— Hardness test

The hardness property of the samples produced was determined using Brinell hardness tester with indenter ball diameter of 20 mm and maximum load of 4000 N. The impression or indentations created on the composites were measured across at least two diameters at right angles to each other and the average values were obtained. The Brinell Hardness Number (BHN) was calculated using equation 1 [18].

WATER ABSORPTION TEST

Each of the sample's water absorption rate was determined by soaking the composite samples in water for 24 hours. The initial weight of each sample was taken and recorded as W_o before soaking in water. After 24 hours, samples were brought out, cleaned to remove water on the surfaces, re-weighed and recorded as W_1. Differences in initial and final weights of each sample were then used to determine water absorption rate. This was calculated using equation 1.

$$\text{Water absorption rate (\%)} = \frac{w_1 - w_0}{w_0} \times 100 \qquad (1)$$

RESULTS AND DISCUSSION

— Elemental compositions of the eggshell

The results of the EDS analysis revealed the elemental compositions of the eggshell presented in Table 2. The components of the eggshell as shown in Table 2 are in descending order of Ca, O, k, Al, Na, Mg and lastly Si. This implies that the major components are Ca, O and k. This result is similar to results obtained by Jenniffer *et al.* in their studies [19].

Table 2: Elemental compositions of the egg shell particles

Elements	Ca	Mg	Na	Al	O	K	Si
Percentage Weight Composition (%)	80.1	0.21	0.35	0.36	11.6	7.3	0.08

— Tensile test

Figure 1 showed that composite sample F (3 wt. % wood dust, 10 wt. % egg shell particles and 87 wt. % epoxy resin) has the highest tensile strength of 34.87 MPa, while composite sample B (10 wt. % wood dust and 90 wt. % epoxy resin) has the lowest tensile strength of 30.05 MPa. The superior tensile strength of the composites compared to the control sample A (100% epoxy resin) may be attributed to the presence of the wood dusts and egg shell particles in the matrix as natural fibres which possibly lock up dislocations and improves the strength and stiffness of the composites [20] and yet maintain some ductility. Ductility is a measure

of how much strain a material can withstand before rupturing, that is, its ability to stretch before failure [21,22]. Under loading, Composite sample C (10 wt. % wood dust, 3 wt. % egg shell particles and 87 wt. % epoxy resin) showed appreciable amount of ductility.

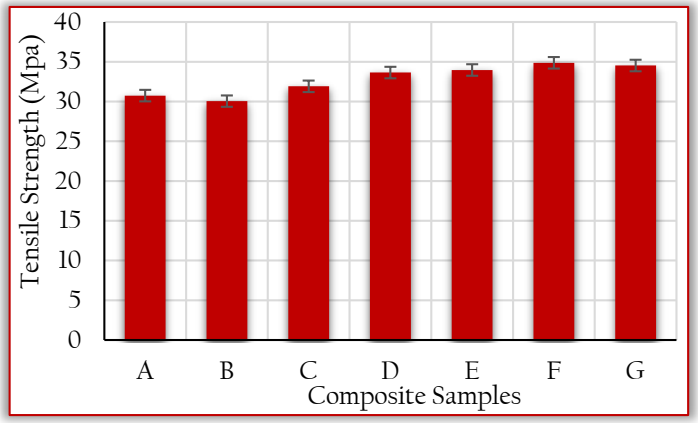

Figure 1: Tensile strength of the composites

— **Flexural test**

Figure 2 showed the effect of wood dust and egg shell particles addition on the flexural strength of the composites. Sample E (10 wt. % wood dust, 10 wt. % egg shell particles and 80 wt. % epoxy resin) has the highest flexural strength of 45.70 MPa, while sample C (10 wt. % wood dust, 3 wt. % egg shell particles and 87 wt. % epoxy resin) has the lowest flexural strength of 36.85 MPa. The flexural strength of control sample A (100% epoxy resin) is 29.59 MPa. It was also observed from the results that the flexural strength was enhanced at higher content of egg shell particles. Lower particle size of the egg shell compared to that of the wood dust may be responsible for the enhanced flexural strength.

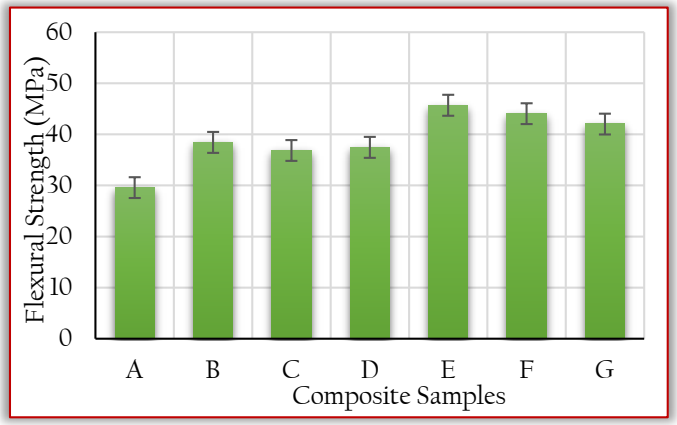

Figure 2: Flexural strength of the composites

— **Hardness test**

Generally, significant improvement in hardness was observed in all composition of the samples as presented in Figure 3. Composite sample G (5 wt. % wood dust, 10 wt. % egg shell particles and 85 wt. % epoxy resin) possessed highest hardness value compared to all other investigated samples. Highest hardness value obtained here may be due to higher quantity of egg shell particles compared to the quantity of wood dust in the composition of the sample. This result is consistent with the observation of Hassan *et al.* [9]. Improvement in hardness of these composites is an indication that they would have good wear resistance, compared to unreinforced sample.

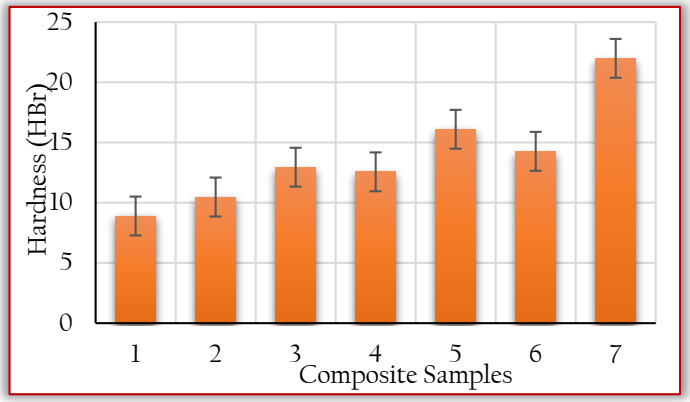

Figure 3: Hardness of the composites
where: 1 = A, 2 = B, 3 = C, 4 = D, 5 = E, 6 = F, and 7 = G on the graph

— **Water absorption test**

Figure 4 showed water absorption test results obtained after 24 hours of soaking the composites. The control sample A (100% epoxy resin) has the least water absorption rate of 2.62 %, while composite sample D (10 wt. % wood dust, 5 wt. % egg shell particles and 85 wt. % epoxy resin) has the highest water absorption rate of 5.91%. From the results, it was noted that the composites with higher quantity of wood dust absorbed more water as a result of hydrophilic nature of wood dust. This is consistent with the finding of Narayan and Antaryami [23]. Conversely, composites with higher quantity of egg shell particles absorbed less water. This may be attributed to lower porosity of egg shell particles compared to the wood dust.

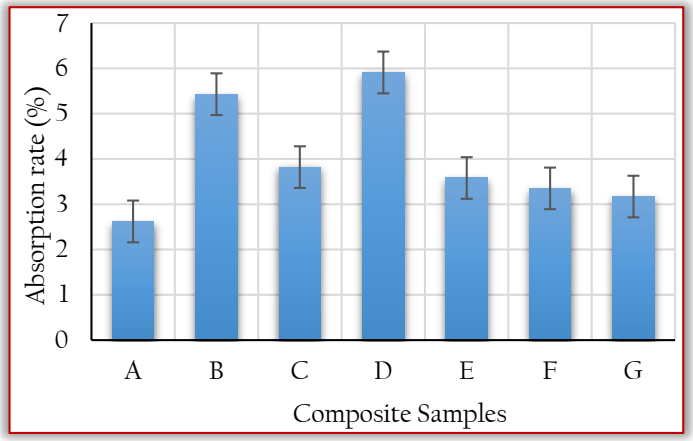

Figure 4: Water absorption rate of the composites

CONCLUSIONS

The following conclusions have been drawn from the results of this study:

— The tensile strengths of the composite increases with addition of reinforcement materials and maximum at 3wt.% wood dust and 10wt.% egg shell particles.

— The flexural strengths of the composite increases with addition of reinforcement materials and maximum at 10wt.% wood dust and 10wt.% egg shell particles.

— The hardness value of the composite increases with addition of reinforcement materials and maximum at 5wt.% wood dust and 10wt.% egg shell particles.

— The water absorption rate of the composite increases with increasing percentage of wood dust. This may be attributed to the hydrophilic nature of wood dust.
— Mahogany wood dust and egg shell particles which are regarded as wastes were found suitable in the production of reinforced epoxy composites by open moulding technique.

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THE MAIN PHYSICAL, HYDROPHYSICAL AND CHEMICAL ATTRIBUTES OF SOME VERTISOLS FROM OLT COUNTY, ROMANIA

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Abstract: The the main physical, hydrophysical and chemical attributes of some Vertisols from Olt county were investigated. The field study was carried out on agricultural area in four soils, from each pedogenetic horizon were collected soil in disturbed samples and undisturbed samples for laboratory analysis. The soil classification was made according WRB 2014 and SRTS 2012, and the investigated soils were classified as Vertisols. In the studied soils, the granulometry data showed a clay texture in all the pedogenetic horizons. According to the values of Saturated hydraulic conductivity (Ksat), most of the studied horizons had low and very low permeability. Useful water capacity (UWC) was obtained by calculation, as the difference between wilting coefficient and field water capacity, and in most of the horizons of the investigated soils, recorded very low values. Moreover, low values of draining capacity (DC) pointed out the studied soils have aeration, permeability drainage deficiencies. The studied Vertisols, in top soil, show moderat acid to low acid pH, low humus content (2.72–3.34%), low content of Pm and high content of Km.

Keywords: Vertisols, Olt County, physical, hydrophysical, chemical attributes

INTRODUCTION

Vertisols are defined as soils with distinct characteristics due to clayey texture and swelling mineralogy (*Somasundaram et al., 2018*). According to Soil Survey Staff (2014), Vertisols are soils with "a layer 25 cm or more thick, within 100 cm of the mineral soils surface, that has either slickensides or wedge-shaped peds that have their long axex tilted 10 to 60 degree from the horizontal" and 30 % or more clay in the first 50 cm of soil profile and cracks that open and close periodically.

However, WRB, 2014 described Vertisols as soils with high content of clays and high proportion of swelling clays, with deep craks from surface when dry out.

In Romanian System of soils classification (*SRTS, 2012*), Vertisols are soils with contractile-swelling properties (z) at the surface or at most 25 cm and a vertic horizon (Bzy) extending to at least 100 cm or up to the horizon R or C, if these appear above 100 cm). The color of the humic horizon, relatively uniform and deep, has values ≤ 3.5 and chrome ≤ 2. Vertisols have sliding faces oblique (10-60°) to the horizontal, glossy, sometimes striated, appearing on a minimum thickness of 25 cm in the subsurface horizon, large structural elements with sharp angles and edges, in one of the sub-horizons (*SRTS, 2012*).

In the conditions of our country, Vertisols is a relict intrazonal soil, whose spread is related to certain forms of relief (Piedmont plains, platforms, high terraces, depressions) at altitudes between 100 and 600 m. The evolution of these soils was made on clayey materials, of alluvial-proluvial nature, predominantly swelling.

The materials are, on the whole, poorly carbonated and hardly permeable (*Paltineanu et al.,2003; Blaga et al., 2005*). The climate is characterized by an average multi-annual temperature of 10-11^{0}C and an average multi-annual precipitation between 530 and 630 mm, with a moisture deficit during July-October and a surplus in the winter-spring months, which determines a water regime in the soil with large variations between seasons. (*Florea and Buza, 2004*). In Romania, Vertisols are spread on 430,000 ha, respectively, 1.8% of the total area of Romania (*Florea and Buza, 2004*) and most of Vertisols and soils with vertic characters located in the south and west of the country (*Paltineanu et al., 2003*). Generally, the Vertisols properties are known world-wide, but due to different environmental conditions, these characteristics are different from one region to another (*Jean Pierre et al., 2019; Lepre C. J. 2019; Kovda et al., 2017; Pal et al., 2012; Dudek et al., 2019; Azinwi Tamfuh et al., 2018*). So is important to do detailed investigation in a specific area

In this paper are studied the main physical (particle size distribution, bulk density, total porosity, saturated hydraulic conductivity, degree of compaction, resistance to penetration), hydrophysical (hygroscopicity coefficient, wilting coefficient, field water capacity, useful water capacity, total water capacity, draining capacity) and chemical (soil reaction, humus content, total nitrogen, mobile phosphorus and mobile potassium contents) features of some Vertisols from Olt County.

MATERIALS AND METHODS

For the investigation of the main physical, hydrophysical and chemical properties of some Vertisols, were chosen 4 sites from Olt County, located in the south of the country. The relief of Olt County is characterized by two major types of structural units in its territory: orogen and platform. The orogen units are highlighted by hilly with an altitude of 200-400 m, being part of the Getic Piedmont, which occupies a third of its extent in the northern part of county. The

platform units correspond to the plain relief, having altitudes of 70–200 m, which fall into the Romanian Plain, which accounts for 2/3 of the county surface. Due to its position in the southwest of the country, the climate of Olt County belongs to the temperate-continental type. The average monthly air temperature values according to the meteorological stations in the territory are 11.3 ºC in Caracal and 10.9 ºC in Slatina, values closely related to the general conditions of this area where the continental climate predominates.

Soil samples. Four soils profiles were dug until 100 cm depth, three of them were located in piedmond plain and 1 profile in terraces. The land use were arable for three sites and grass land for one sites. The field descriptions of soil profiles were made according to Munteanu and Florea, 2009 and Raducu, 2019. From each pedogenetic horizon soil were collected soil in disturbed samples for particle size distribution, hygroscopicity coefficient and chemical characteristics. Also, soil samples were collected from undisturbed samples *by using a core sampler (cylinder method), in three* repetitions, in order to determine the bulk density, total porosity, saturated hydraulic conductivity, resistance to penetration.

Laboratory analysis. The soils texture was determined by gravimetric method. Coefficient of hygroscopicity was obtained by using Mitscherlich method. The methodology used for determining the bulk density, total porosity, saturated hydraulic conductivity, resistance to penetration is given in detail in the papers *(Florea et al., 1987; Canarache, 1990; Dumitru et al., 2009)* and corresponds to the standard method. The hydrophysicals parameters (wilting coefficient, field water capacity, useful water capacity, total water capacity, draining capacity) were obtained by calculation (*Dumitru et al., 2009*).

Soil reaction (pH) was determined potentiometric method, in water suspension (1:2.5). Organic carbon content (Corg, %) was meaured by wet combustion procedure (Walkley-Black method modified by Gogoaşă). The available phosphorus and potassium contents were determined by the Egner-Riehm-Domingo procedure, by extraction with the ammonium lactate acetate. The interpretation classes of studied properties are presented in MESP, 1987 (*Florea et al., 1987*). The soil classification was made according WRB 2014 and SRTS 2012, and the investigated soils were classified as Vertisols.

The statistical analysis (minimum values, maximum values, arithmetic mean, median, standard deviation, coefficient of variation) was performed using Microsoft Excel 2010.

RESULTS

PHYSICAL ATTRIBUTES. In table 1 are listed the basic statistics of the physical properties of examinated soils. In the studied soils, the granulometry data showed a clay texture in all the pedogenetic horizons (fig. 1). In the soil profile, clay (≤ 0,002 mm) content layed between 44.1% and 69.1%, with an average of 60.2% and median of 60.3%. Content of silt (0.02-0.002 mm) belong to the field of 17.7-32%, with an average of 22.87% and median of 23.8%. Fine sand (0.2 - 0.02 mm contents) ranged from 6.9 to 20.1 % with an average of 13.4% and coarse sand (2 -0.2 mm) content was between 1.6 to 7.6%, with an average of 3.5%. The highest CV was in coarse sand (52.7%). Vertisols or horizons of vertical soils in our country generally contain over 45-50% clay (*Paltineanu, et al., 2003*), however in soils from West of country were found a clay content average of 61.76% (*Bertici et al., 2005*).

In the fig. 2 are presented the variation of bulk density, total porosity, degree of compaction, saturated hydraulic conductivity, and resistance to penetration on soil profiles.

Table 1. The basic statistics of the physical attributes of examinated soils

	Clay	Silt	Coarse Sand	Fine sand
	%			
Minimum	45.60	17.70	0.60	6.90
Maximum	69.10	28.30	7.60	23.50
Median	56.00	24.20	2.40	16.70
Mean	56.44	24.06	2.71	16.77
Standard deviation	6.33	3.18	1.63	4.48
Coef. Variation,%	11.21	13.23	60.13	26.70

	DA	PT	Ksat	Gt	RP
	g/cm³	% v/v	mm/h	% v/v	kgf/cm²
Minimum	1.30	44.80	0.30	4.86	33.00
Maximum	1.48	51.50	4.23	18.29	54.00
Median	1.40	47.70	0.40	12.08	44.00
Mean	1.39	47.99	1.24	11.64	43.33
Standard deviation	0.05	1.84	1.29	3.34	6.00
Coef. Variation,%	3.60	3.83	103.46	28.66	13.84

Bulk density (BD, g/cm³) is considered one of the most important physical soil properties, which determines many physical properties of the soil, such as compaction and hydrophysical properties of soils. Bulk density (BD) was between 1.30 g/cm³ and 1.48 g/cm³, the values in the same variation field were found by Rogobete and Bertici (2006). The BD values greater than 1.25-1.30 g·cm^{-3} could cause yield loss due to poor soil aeration (*Borek Ł., 2019*). In case of clay texture, high and very high values of BD characterize moderately and strongly compacted soils (*Canarache, 1990*).

Total porosity (TP, % v/v) varied from 44.8 (% v/v) to 51.7 (% v/v), with an average of 47.9 (% v/v). According to Canarache (1990), for Vertisols, total porosity is generally between 48-52%, but there are frequent cases in which total porosity falls below 45%, the very compacted soils could reach even values of 42% (*Paltineanu, et al., 2003*). The Vertisols are known as poor porosity and aeration soils (*Kadu et al., 2003; Pal et al., 2012*).

The degree of compaction (DG, % v/v), Soil compaction due to agricultural activities could be a serious threat to yield and soil ecological functions (*Guimarães et al., 2017*). DG is one of the indicators that characterize the soil settlement, is obtain by calculation according to the total porosity and the soil texture. DG was in the range of low compacted (4.86 % v/v)

to strongly compacted (18.29 % v/v) and the average value belongs to medium compacted (11.64 % v/v).

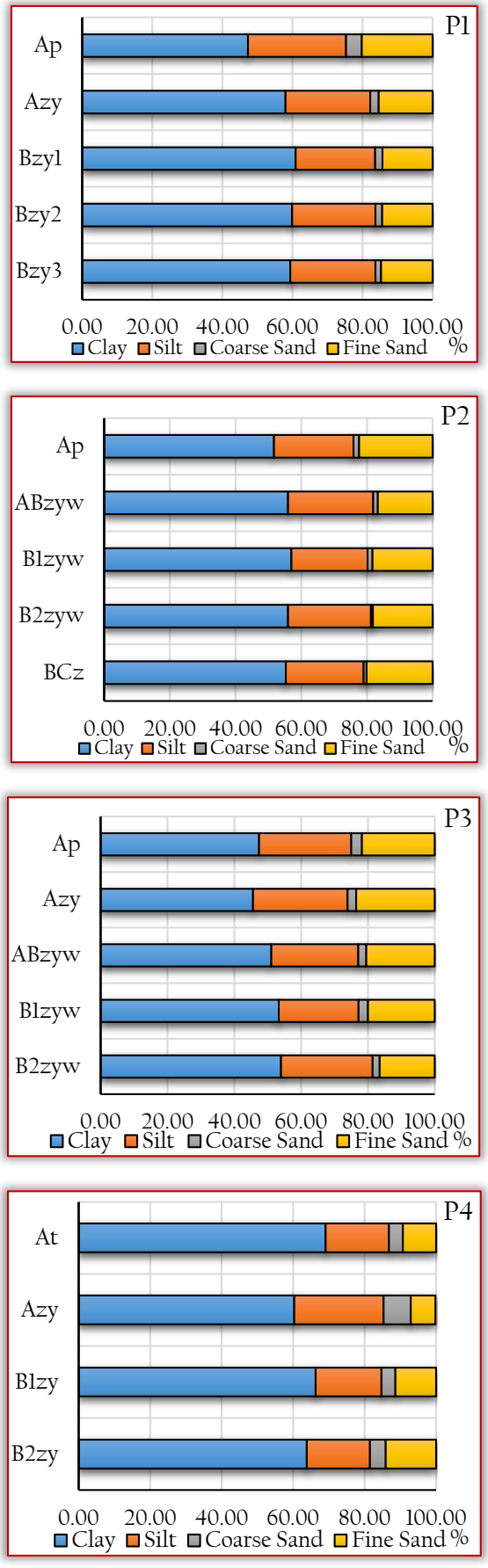


Figure 1. The variation on soil horizons of particule size distribution

Saturated hydraulic conductivity (Ksat, mm/h) characterizes the soil permeability to water for the control section and could be affected by "biological activity, swelling, aggregate failure and dispersion of clays" *(Ranade and Gupta, 1987)*.

In the examinated soils, the highest *Ksat*, value was 4.23 *mm/h*, the median values was very low (0.4 *mm/h*) and the high value of variation coefficient was noticed (103.5%). So, most of the studied horizons had low and very low permeability.

Saturated hydraulic conductivity sharp decreased from top soil to very low values (0.3 *mm/h*) in the lower part of Profiles 1 and 2 and gradually decreased to deeper horizons of profiles no 3 and 4 (figure 2).

A gradually decresead on soil profiles of Vertisols were noticed also by Oosterbaan and Nijland, 1994, which considere that the topsoil is made more permeable because of physical and biological processes.

The loss of Vertisols hydraulic activity seems to be determined by swelling (Ranade, Gupta, 1987).

Resistance to penetration (RP, kgf/cm^2) predominantly increasing with depth and layed between medium (33 kgf/cm^2) and high values (54 kgf/cm^2), with a medium value of 43 kgf/cm^2. *Dumitru et al. (2011)* found a mean value of 47.4 kgf/cm^2 in the 0-25 layer of Vertisols.

Resistance to penetration increases as clay content and bulk density increase *(Canarache, 1990)*.

HYDROPHYSICAL ATTRIBUTES

In table 2 are listed the basic statistics of the hydrophysical properties of examinated soils and in the fig. 3 are presented the variation of hygroscopicity coefficient, wilting coefficient, field water capacity, useful water capacity, total water capacity, draining capacity on soil horizons.

Table 2. The basic statistics of the hydrophysical attributes of examinated soils

	CH	CO	CC	CAU	CT	CD
	% g/g					
Minimum	11.00	16.50	24.09	3.46	30.27	1.70
Maximum	15.70	23.55	31.20	10.20	39.62	10.50
Median	13.95	20.93	26.52	5.00	34.07	8.70
Mean	13.74	20.61	26.83	5.90	34.53	7.71
Standard deviation	1.27	1.91	2.00	2.02	2.58	2.32
Coef. Variation, %	9.25	9.25	7.46	34.32	7.48	30.10

Hygroscopicity coefficient (HC, % g/g) recorded values in the field of 11-15.7 (% g/g), but in the most of the horizons values were over 13 (% g/g) (tab. 2). These results are in line with results obtained by the Paltineanu, et al. (2003), which noticed values between 12 and 15 % v/v 9 (tab. 2).

Wilting coefficient (WC, % g/g) range between 16.5% g/g to 23.35 % g/g, with a mean of 20.61% g/g, and are very high on the whole profile of the all investigated soils. In case of Vertosols, high values of WC were, also, reported by Tamfuh et al. (2018). Field water capacity (FWC, % g/g) expressed the water content that a soil retains in a sustainable manner and depends mainly on the clay and bulk density. The values of field water capacity were, generally, high in Profile 1 (26.5-28.5% g/g) and 4 (26.3-31.2 % g/g) and high to mediu in the Profile 2 (24.4-29.1 % g/g) and 3 (24.1-26.2% g/g). Except

Profile 4, the values of FWC recorded slighter decrease on the soil profile (figure 2).

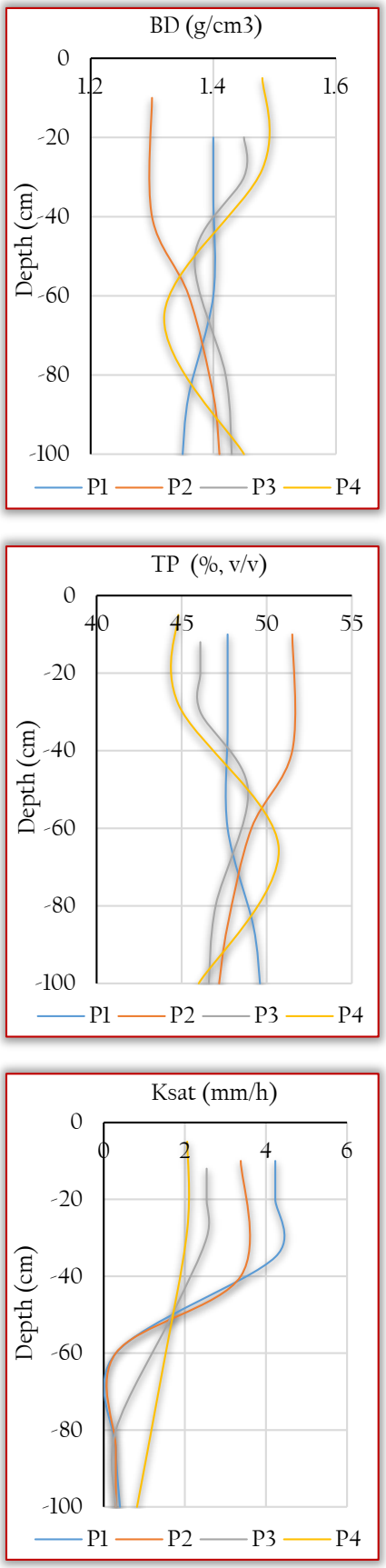


Figure 2. The variation on soil profiles of bulk density, total porosity, degree of compaction, saturated hydraulic conductivity, resistance to penetration

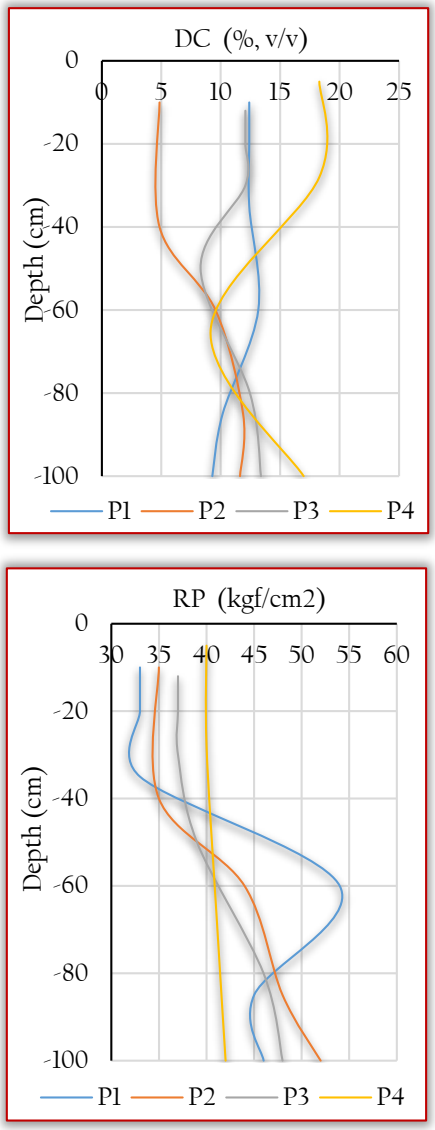


Figure 2. The variation on soil profiles of bulk density, total porosity, degree of compaction, saturated hydraulic conductivity, resistance to penetration (continuing)

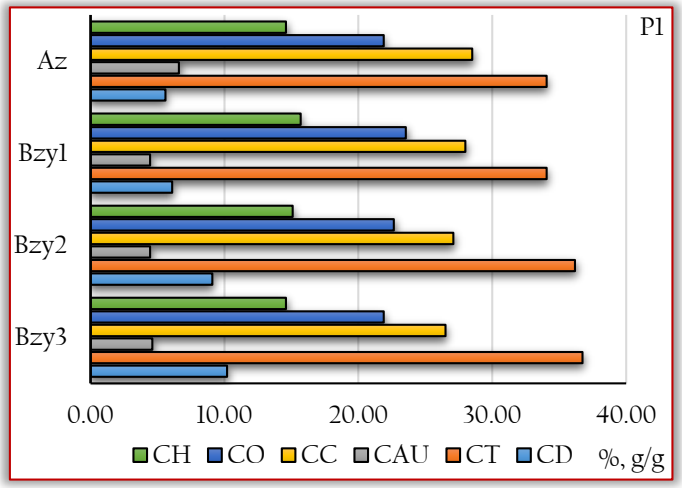
Useful water capacity (UWC, % w/w) it is a key indicator of the potential water reserve and is obtained by calculation, as the difference between wilting coefficient and field water capacity. In the examinated profiles, UWC is low to very low (3.46-10.2 % g/g), but in most of the horizon, the recorded values were very low (‹ 8% g/g). The total capacity of the soil water (TC, % g/g) means the maximum water quantity that soil could retain when its entire porous space is filled with water. The values of TC were high (30.27-39.62% g/g) on the whole profile of investigates soils. Draining capacity (DC % g/g) of soil is the maximum water amount that soil could release. Vertisols are known as poorly drained soils (*Paltineanu et al., 2003; Lepre, 2019*). The DC values were extremly low to low (1.7-10.5 % g/g), with an average belong to low value (7.7 % g/g). According to the DC values, the studied soils have aeration and permeability deficiencies and excess water potential.

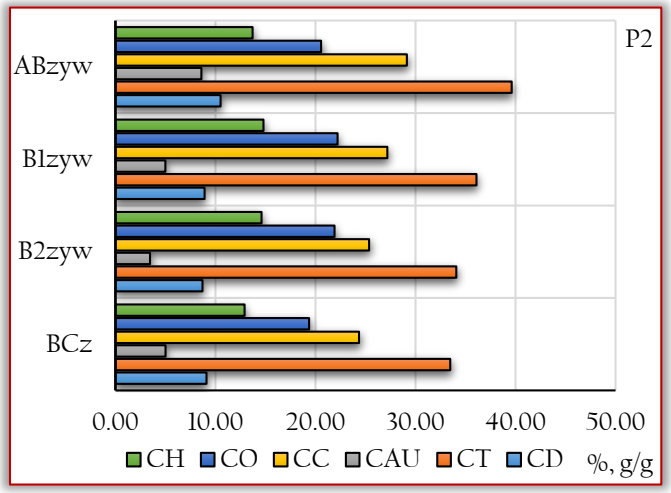
In table 3 are listed the basic statistics of the chemical properties of exanimated soils and in the figure 3 are presented the variation of soil reaction, humus content, total

nitrogen, mobile phosphorus and mobile potassium contents on soil profile.

Table 3. The basic statistics of the chemical attributes of examinated soils.

	pH	H %	Nt %	Pm mg/g	Km, mg/kg
Minimum	5.13	0.96	0.09	0.50	200.00
Maximum	8.11	3.43	0.25	18.10	356.00
Median	6.27	2.14	0.15	6.50	236.00
Mean	6.30	2.21	0.15	7.03	247.00
Standard deviation	0.79	0.81	0.04	5.68	44.57
Coef. Variation, %	12.50	36.63	28.98	80.84	18.04





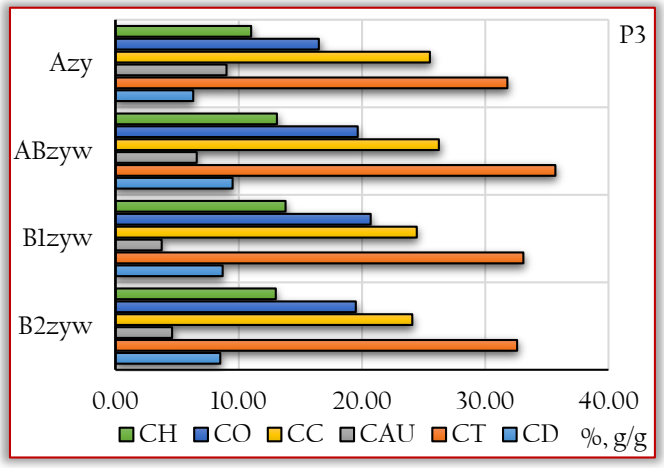


Figure 3. The variation of CH, CO, CC, CAU, CT and CD on soil horizons

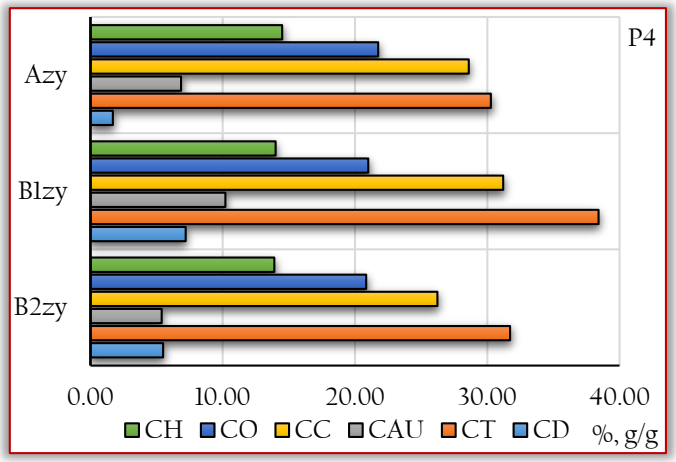
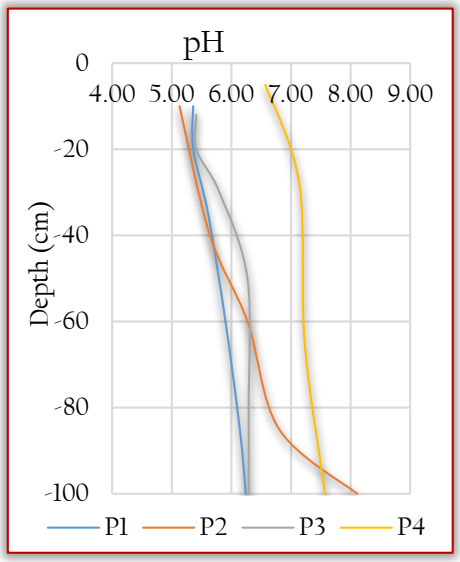


Figure 3. The variation of CH, CO, CC, CAU, CT and CD on soil horizons (continuing)

Soil reaction (pH in water) increased on the soil profile from moderate acid (pH=5.4) to low acid (pH=6.3) in case profiles no 1 and 3, from low acid (pH=6.6) to low alkalinity (pH=7.6) in case of profile no 2, and from moderate acid (pH=5.1) to low alcalinity (pH=8.11) in case profiles no 4 (figure 3).



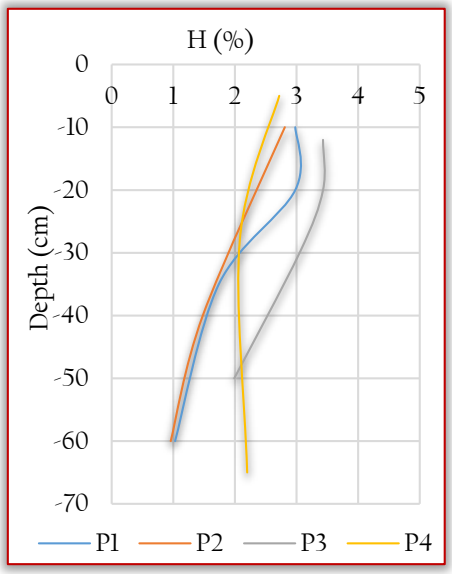
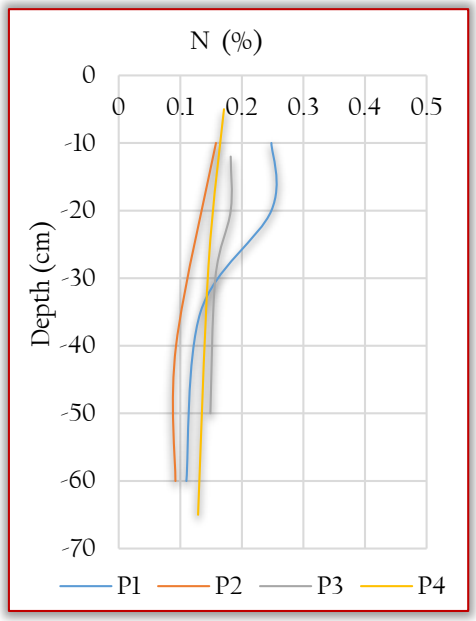
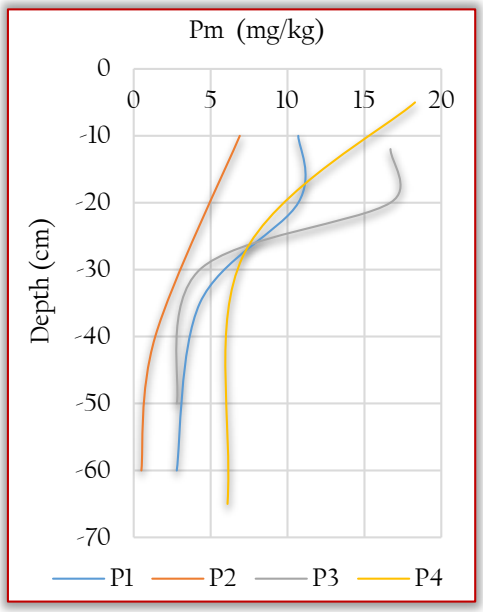


Figure 4. The variation of pH, H, N , Pm and Km on soil profiles





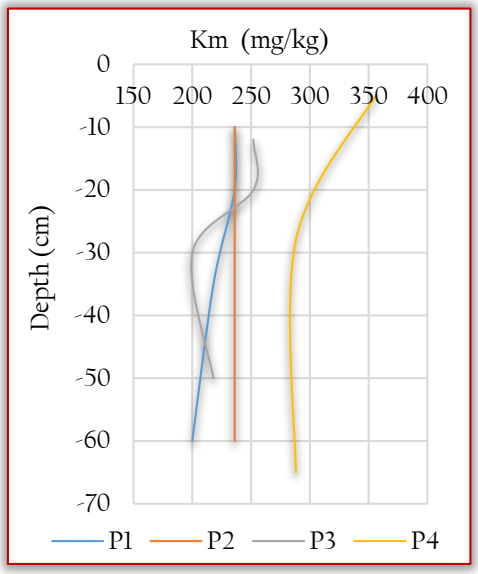


Figure 4. The variation of pH, H, N , Pm and Km on soil profiles (continuing)

Humus content (H,%). Vertisols are characterized by relatively high values of humus content, both in the upper horizon (2.0-3.3%), as well as on the profile with more than 1% up to 110-120 cm depth (*Paltineanu et al., 2003*). In investigates soil, humus ranges from 3.34% to 2.72% in the upper part of soil profile and decrease o up to 2.2% at the 65 cm depth in case of P4 and up to 0.96 % at the 60cm depth in case of P2 (figure 3). In upper horizons, the organic carbon content reported in other studies varies from 3.23% (*Kovda et al., 2017*) to 1.6-2.5 % (*Dudek et al., 2019*). *Total nitrogen content* (Nt, %) range from 0.17%-0.25% in the upper part of soil profile and decreased gradually up to 0.11%, except P2 were Nt decrease sharply from 0.16% in top soil to 0.09% under 20 cm depth.

Mean mobile phosphorus contents (Pm, mg/kg) lay between low (18 mg/kg) to very low values (6.9 mg/kg) in the upper part of soil and from very low (6.1 mg/kg) to extremely low values (0.5 mg/kg) at the 60 cm depth. *Mean mobile potassium contents* (Km, mg/kg) was very high – high (356-288 mg/kg) in the first 50 cm of the P4 and high (200-256 mg/kg) in the other studied soils

CONCLUSIONS

The studied of the main physical, hydrophysical and chemical attributes of some Vertisols from Olt County pointed out the following:

- the granulometry data showed a clay texture in all the pedogenetic horizons, the mean of clay, silt, fine sand and coarse sand were: 60.2%, 22.8%, 13.4% and 3.5%, respectively;
- the bulk density (BD) was between 1.30 g/cm^3 and 1.48 g/cm^3, and total porosity (TP) varied from 44.8 (% v/v) to 51.7 (% v/v), with an average of 47.9 (% v/v), these values are in the field of poor soil aeration with implications of yield;
- the values of Saturated hydraulic conductivity (Ksat), in the most of the studied horizons, had low and very low permeability;
- the degree of compaction was in the range of low compacted (4.86 % v/v) to strongly compacted (18.29 % v/v) and the average value belongs to medium compacted;
- resistance to penetration predominantly increasing with depth and layed between medium (33 kgf/cm^2) and high values (54 kgf/cm^2), with a medium value of 43 kgf/cm^2;
- the useful water capacity (UWC) in most of the horizons of the investigated soils, recorded very low values
- the draining capacity (DC) recorded low values of draining capacity (DC) highlighted that the studied soils have aeration, permeability drainage deficiencies;
- the examinated Vertisols, in top soil, show moderat acid to low acid pH, low humus content (2.72–3.34%), low content of Pm and high content of Km.

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CO_2 EMISSION ASSESSMENT OF CONSTRUCTION AND WASTE MATERIALS IN THE CONTEXT OF CIRCULAR ECONOMY: CASE STUDY OF PROJECT "CORRIDOR X"

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Abstract: Assessment of the environmental impact of construction materials and construction and demolition (C&D) waste is very important in the context of circular economy and sustainable development. This paper shows calculated CO2 emissions using data on the quantities of used construction materials and the amount of generated construction and demolition waste (mostly inert material), using the IPCC 2013 method in the case of "Corridor X" project. "Corridor X" project represents one of the capital projects in Serbia and in the Balkan region. This analysis covers mainly road infrastructure. In this paper, data related to all construction activities, construction materials and construction and demolition waste are used. This analysis which is related to the assessment of the impact concerning all construction activities on the project "Corridor X" in the form of CO2 emissions, thereby contributing with data and raising awareness of the principles of circular economy.
Keywords: Environment, construction and demolition waste, circular economy

INTRODUCTION

It is estimated that around 374 million tons of construction and demolition (C&D) waste is generated annually in the European Union (EU) (excavated soil is not included), representing 31% of the total amount of waste generated [1]. No specific directive on this type of waste has been published within the European Union, only the Waste Framework Directive 2008/98/EU mentions measures that correlate with C&D waste. According to this directive, it is foreseen that by 2020, the reuse, recycling and revitalization of materials (including excavation operations) should be increased to the at least 70% by weight, not including excavation materials.

GENERAL ASPECTS OF C&D WASTE

Materials that remain on site immediately after the completion of construction or demolition of construction or infrastructure facilities, may be considered as C&D waste.

Such materials (C&D waste), are more difficult to process in terms of their reuse in construction, which is imposed, among other factors, by higher costs. Thus, for instance, waste material generated when removing the asphalt road could be used to build another asphalt road. The only requirement for C&D waste that will be reused in that case, is to ensure its inertness from an environmental point of view.

Recycling of C&D waste in the form of obtaining reusable materials includes the sorting of waste, which can be done during the construction or demolition of the construction infrastructure itself, and then the treatment of each of the components, according to the properties and potential applications of such materials. The recycling methods for each of the C&D waste materials are at the forefront of all the factors that are essential for the treatment of C&D waste, both from the point of view of their practical feasibility and from the point of view of their economic justification. Thus, for example, among the companies involved in the recycling of C&D waste, wood is the most commonly sought after construction material, primarily due to its potential for use as an energy source. For some other materials, such as metals and its alloys, there is already an elaborate global market for products derived from recycled materials. On the other hand, processed concrete has both a limited market and a limited scope [2].

EXCAVATED MATERIALS AS A POTENTIAL RESOURCE

This material is formed during excavation processes in various construction activities and its composition can be extremely heterogeneous, with contents such as organic soil, loam, gravel, sand, old construction waste. Currently, the main purpose of this material is to cover the pits in the ground after excavation of sand, gravel or other construction materials. Excavated material that does not contain impurities that could actually or potentially contaminate soil or groundwater, can be used directly. This, in fact, contributes to the restoration of the site and the restoration of the environment to its original state. It is negligible that the excavated material used to cover the pits will ever be used again, but it is also considered that its use in soil revitalization and site restoration operations will close cycle of used construction material. The excavated material is almost always directly used, without the need for sorting.

CONSTRUCTION INDUSTRY AND THE ENVIRONMENT

The conventional construction sector is one of the largest consumers of raw materials. Globally, it is estimated that construction industry is consuming:

— 50% of all resources,
— 45% of energy for heating, cooling and lighting of buildings, and 5% during the construction,
— 40% of water for sanitary and other purposes,
— 60% of agricultural land,
— 70% of wooden products.

Many of the current construction materials used in the construction activities have been processed industrially (cement, steel, aluminum, sand, stone, clay, petroleum), which in many cases have negative effect to the environment and biodiversity.

Global annual carbon emissions as a result of construction activities reached its peak, at least temporarily, from around 9.5 gigatons of CO2 (GtCO2) in 2013, and then declined to 9 GtCO2 in 2016. The energy intensity of the construction sector (in terms of energy consumption per m2) continues to improve at an annual rate of about 1.5%. The Paris agreement marked a milestone in the form of calls for curbing global warming. The rapid implementation of energy-efficient and low-carbon solutions in the construction sector can improve sustainability in the construction sector.

The potential for energy savings and emissions in the construction sector remains largely untapped due to the continued use of less efficient technologies, with the lack of efficient policies and poor investment in sustainable infrastructure. Consumer choice and behavior also play a key role. However, energy-efficient, low-carbon products are already available in many markets [3].

AIM OF THIS WORK

The aim of this work is to show quantitative and comparative analysis of CO2 emissions, consequently by using waste construction materials instead raw construction materials within the "Corridor X" project. In accordance with the principles of circular economy, one of the goals is to raise awareness of waste utilization (in the form of reuse or recycling) in order to reach the best possible solution that meets environmental aspects.

"CORRIDOR X" PROJECT

Corridor X is one of the most important Pan-European transport corridors that crosses Serbia and connects Austria, Hungary, Slovenia, Croatia, Serbia, Bulgaria, North Macedonia and Greece. With this project, the transport system of the Republic of Serbia becomes compatible with the transport system of the European Union, with a tendency for further modernization in order to enable the Republic of Serbia to comply with the European Union standards in the field of transport.

The implementation of this important project will lead to a general acceleration of traffic, improve the level of service, facilitate international trade flows and transport of passengers. The new highway will have a positive impact on commercial and trade activities in the region and will contribute to regional development and cohesion in the wider Balkans.

The "Corridor X" project is considered to be one of the capital projects in the Republic of Serbia. Corridor X includes the construction of 160 kilometers of highway south of Nis - Section E80 from Prosek to the Bulgarian border in Dimitrovgrad and E75 - from Grabovnica to Levosoje [4].

Assumption is that within the project "Corridor X", some of the construction materials with the highest inflows are:

— concrete,
— steel,
— asphalt.

METHODOLOGY

This research shows quantitative and comparative analysis of construction and waste materials within the "Corridor X" project and environmental impact in the form of CO2 emissions. The data provided were used to calculate effects over a given time horizon resulting from the unit of mass emission related to the referent gas (GWP_{100a}), in this case the CO2 emission was calculated using the IPCC 2013 method (Intergovernmental Panel on Climate Change). The functional unit in this case is 1 kg of construction materials and C&D waste. In this analysis, the *Ecoinvent 3.2* database was used to obtain benchmarks relating to the analyzed construction materials and C&D waste.

LIFE CYCLE ASSESSMENT (LCA)

Life Cycle Assessment (LCA) is an analytical instrument that sets the framework for analyzing the environmental impact of products. ISO 14040 and 14044 provide the principles, frameworks, requirements and instructions for conducting the life cycle assessment of products and/or services. The main objective of impact assessment is to identify and establish links between the life cycle of products and services and the potential environmental impacts [5,6].

The LCA examines environmental aspects and potential environmental impacts (example, resource utilization and environmental effects of pollutant components) over the lifetime of raw material extraction products, through production, use and end-of-life treatment, recycling and dispose.

LCA as a tool can help with:

— Identifications and impacts within activities (example, greenhouse gas emissions),
— Ensuring all aspects of the environment throughout the life cycle (example, equal consideration of emissions into the air, water and land during the construction, operation and decommissioning of plants),
— Identifying opportunities to improve the economic and environmental performance of different technologies, projects, products and services,
— More effective communication with various stakeholders interested in information on the potential consequences of projects and technological options (example, LCA development process requires the involvement of different stakeholders, establishing communication and providing information on the full impact and/or benefits of certain changes or new production processes).

Also, the LCA can help with:

— Identifying opportunities to improve the environmental protection of products at different stages of their life cycle,
— Informing the various target groups that make decisions in industry, government and non-governmental organizations (example, for strategic planning, prioritization, design or project modification for products or processes),

— Selection of appropriate environmental performance indicators (indicators), including procedures for measuring pollution.

RESULTS

In this chapter, the results of the analysis of concrete, steel and asphalt in the form of CO_2 emissions using the IPCC 2013 method are presented. Table 1 presents the unit of emission and CO_2 emissions of concrete, steel and asphalt used.

Table 1. Emission factors per unit for the analyzed materials and calculated kg CO_2 emissions related to the "Corridor X" project [7]

Material	Steel	Waste steel	Asphalt	Waste asphalt	Concrete	Waste concrete
IPPC 2013 (GWP 100a kg CO_2 eq)	2.346	0.0086	0.2897	0.02024	229.7	0.01329

According to the results from Table 1, it is visible that there is significant difference in the kg CO_2 between the products produced from raw materials and waste material.

Since steel, asphalt and concrete are in the most of it parts recyclable, following the principles of circular economy, Figures 1, 2 and 3 present environmental benefits by analyzing CO_2 emissions in the form of recycled construction materials as substitutes for construction materials obtained from primary production.

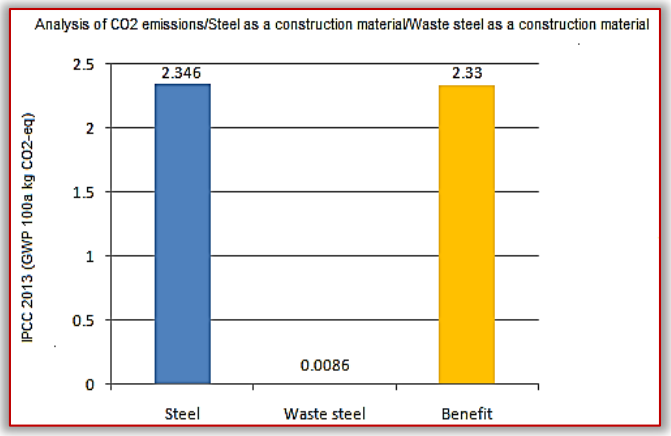

Figure 1. Analysis of kg CO_2 emissions using steel as construction materials and using waste steel in the construction processes [4]

Figure 1 shows the environmental benefit (orange color) as an example of using waste steel instead of steel produced by primary production (blue), which means that reduction in CO_2 emissions is 2.33 kg CO_2.

Figure 2 shows the environmental benefit in the context of reducing kg CO_2 if waste asphalt was used in the project of "Corridor X" project instead of asphalt from primary production, resulting with 0.27 per kg CO_2 in reduction.

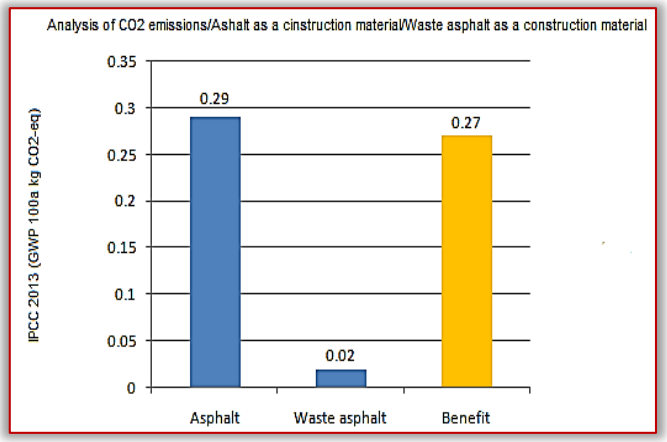

Figure 2. Analysis of kg CO_2 emissions using asphalt as construction materials and using waste asphalt in the construction processes [4]

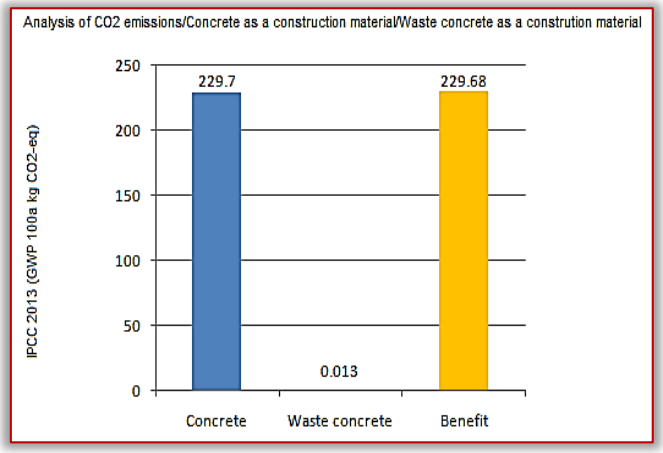

Figure 3. Analysis of kg CO_2 emissions using concrete as construction materials and using waste concrete in the construction processes [4]

Figure 3 shows an environmental benefit in the form of kg CO_2 reduction of waste concrete (aggregates). Concerning concrete, recycled concrete in the form of aggregates can be used in concrete production, although within concrete production itself, cement production industry is one of the largest environmental polluters. In this case, the analysis of kg CO_2 related to the concrete is presented empirically (assuming that the concrete obtained from primary production materials is completely replaced by recycled concrete). If recycled concrete (100%) is used on the "Corridor X" project, CO_2 emissions of CO_2 would be reduced by 229.68 kg.

CONCLUSION

This research considers quantitative and comparative analysis of construction and waste materials, from which it can be concluded that the use of recycled construction materials is an environmental benefit, both in terms of reducing CO2 emissions and conserving the natural resources. In order to justify the benefits of EU waste legislation, a much deeper analysis of the environmental impact of C&D waste should be made. Considering the principles of circular economy, replacing raw materials from primary production with recycled ones, would be a more desirable option, as demonstrated in this analysis. In order

to stimulate the use or recycling of C&D waste, there is a need for end markets. There is also a lack of information and data indicating flows and stocks of C&D waste in Serbia. This analysis is an initial step for further research related to construction materials and C&D waste within infrastructure projects.

Note:
This paper is based on the paper presented at IIZS 2020 – The X International Conference on Industrial Engineering and Environmental Protection, organized by Technical Faculty "Mihajlo Pupin" Zrenjanin, University of Novi Sad, in Zrenjanin, SERBIA, in 08–09 October, 2020

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METHODS OF COLLECTING AIR HUMIDITY FOR THE PURPOSE OF VALORIZATION FOR CROP IRRIGATION

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Abstract: Non-conventional water resources have emerged as means to meet or supplement irrigation demand for reforestation and agriculture in water scarce regions. Irrigation by condensation is an inexhaustible resource of water for irrigation, the combination of high relative humidity, the air temperature and the low temperature of water circulating through a closed loop system. Irrigation by condensation are designed primarily to arid and semi-arid areas, where groundwater is deep and fresh water sources are rare. Air humidity is a potential source of freshwater that is accessible everywhere and can be used for crop irrigation. This paper presents a review of atmospheric water harvesting used for the purpose of valorization for crop irrigation. The aim of this study is to present methods of collecting air humidity for the purpose of valorization for crop irrigation.
Keywords: humidity collecting, irrigation

INTRODUCTION

Climate change is a major challenge for agriculture, water resources and ensuring stability crops being key priorities in the policy of prevention and mitigation of extreme events. Despite the vast amount of water on the planet, most of it (97.5%) is in seas with high salt content, rendering it unsuitable for human consumption, while the rest is foundas fresh water (2.5%). Of this fresh water, 70% is frozen and about 30% exists in the form of moisture or underground aquifers (*Mendoza-Escamilla et al, 2019*).

Non-conventional water resources have emerged as means to meet or supplement irrigation demand for reforestation and agriculture in water scarce regions *(Tomaszkiewicz et al, 2017)*.

Despite the significant value of the potentially extractable fresh water in the world few atmospheric water-harvesting systems are commercially operating currently. In general, any viable atmospheric water-harvesting technology must satisfy five primary criteria: it should be efficient, cheap, scalable, wide-band, and stable enough to operate for a whole year or at last a monsoon season *(Yaodong, 2018)*. Although resultant yields are relatively small, dew positions itself as a viable water resources supplement because it occurs naturally and frequently in many locations globally, particularly in the absence of precipitation or when more traditional water sources are subject to depletion *(Tomaszkiewicz,2015)*.

Irrigation by condensation is an inexhaustible resource of water for irrigation, the combination of high relative humidity, the air temperature and the low temperature of water circulating through a closed loop system. Irrigation by condensation are designed primarily to arid and semi-arid areas, where groundwater is deep and fresh water sources are rare *(Manea et al, 2016)*. The aim of this study is to present methods of collecting air humidity for the purpose of valorization for crop irrigation.

MATERIALS AND METHODS

According to the forms of airborne water, the atmospheric water-harvesting technologies can be divided into two categories: fog water collectionand dew water collection *(Yaodonget al, 2018)*. Atmospheric water can be harvested through passive methods or active methods. Passive methods are suitable for atmospheric humidity that has already condensed to liquid rain, dew or fog *(Nidalet et al, 2017)*. One passive method of atmospheric moisture collection utilizes screens and meshes to hunt dew mist and fog droplets and deposit them into gutters that stream them into collection tanks *(Nidalet et al, 2017)*.

Another method of passive atmospheric water harvesting involves chemical treatment of cotton fabrics to enable them to absorb considerable amounts of water from misty air that can be more than three times of their own weights (*Mendoza-Escamilla et al, 2019*).

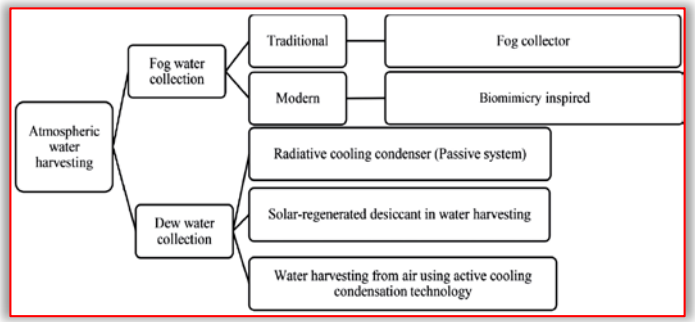

Figure 1. Atmospheric water harvesting technologies (Hasila et al, 2020)

Active harvesting of atmospheric humidity requires special dehumidifiers that condense atmospheric moisture to produce liquid water. Electromechanical / refrigerative dehumidifiers come with refrigerative coils, where moist atmospheric air is forced to pass through the cold coils. This causes the condensation of gaseous vapor into liquid water. This water is then streamed into collection tanks.

A more recent passive method of atmospheric moisture collection utilizes screens and meshes to hunt dew mist and fog droplets and deposit them into gutters that stream them into collection tanks *(Nidalet al, 2017)*.

RESULTS

The usual method to collect fog water is placing a rectangular mesh perpendicular to the wind, which traps fog droplets. When exposed to a foggy environment, water droplets carried by the wind are pushed against the mesh and become trapped. After successive impacts, the droplets grow by coalescence until they are large enough to fall by gravity, and a gutter transports the water to a tank *(Yaodong et al, 2018)*. Research suggests that fog collectors work best in locations with frequent fog periods, such as coastal areas where water can be harvested as fog moves inland driven by the wind.

Figure 2. Fog collector (Domenet al, 2014)

The collection rate of a fog collector is determined by the fog liquid water content (LWC), the size distribution of fog droplets, the size and arrangement of the mesh mate- rial, and the wind speed.

The collection rate of a fog collector is determined by the fog liquid water content (LWC), the size distribution of fog droplets, the size and arrangement of the mesh material, and the wind speed.

The Raschel shade net material from the Chilean manufacturer Marienberg is used in most fog collector applications world-wide. The materials made of food-safe polyethylene and has a fiber width that is effective at collecting fog droplets *(Klemm et al, 2012)*.

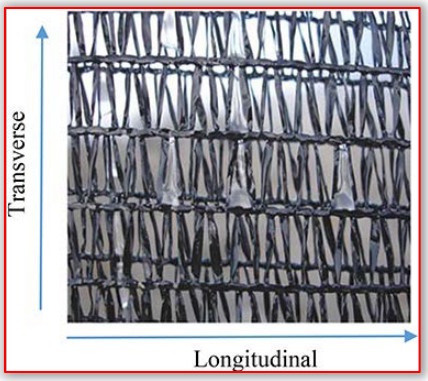

Figure 3. Raschel mesh (http://www.marienberg.cl)

Talaat A. Salem investigated the suitability of harvesting fog and rain water for irrigation using a pilot fog collector for water quantity, water quality and economic aspects. This study proved that fog harvesting is feasible in terms of water quantity, water quality and economy. But it recommends collection of fog at various locations and times, since both water quantity and water quality are variable in time and space *(Salem et al,2017)*.

Sabah A. Abdul-Wahab conducted Experiments using three fog collectors with different local materials: AC filter, green shade filter, and aluminium filter. The results indicated that the total fog water collected during the experimental period of 76 days by AC filter, green shade mesh, and aluminium shade mesh was 995.04, 879.93, and 752.58 L/m2, respectively. The ion concentrations were studied and found to meet World Health Organization drinking water standards. Water from the three fog collectors was found to be of good quality. The results indicated a significant linear association between the collected fog water and the wind speed and rainfall. It was found that fog water collection rates increased with increasing wind speed and rainfall *(Sabah et al, 2007)*.

— Dew Water Collection

There are two main types of dew condenser, the apparatus used to collect dew water, namely radiative (also called passive) and active condensers *(Khalil et al,2016)*. The technology behind radiative dew water collection system is relatively simple as it relies on exploiting the physical processes of dew formation, and no additional energy input is necessary. The technology behind radiative dew water collection system is relatively simple as it relies on exploiting the physical processes of dew formation, and no additional energy input is necessary *(Khalil et al,2016)*.

Figure 4. Dew condenser *(Daniel et al, 2009)*

Studies on passive cooling system include investigation on materials with low emissivity surfaces. Early study on the influence of condensing surface materials to the dew formation has been investigated for Bahrain climatic condition. Three materials: aluminium, glass and polyethylene foils were investigated as the condensation surfaces. From their study, aluminium surfaces were reported to have the highest amount of average dew collected at 3 kg/m2 per hour, followed by glass and polyethylene foils at 0.8 and 0.3 kg/m2 per hour, respectively *(Alnaser and Barakat 2000)*.

Sharan G. investigated three different types of condensing surface, galvanized iron sheet with emissivity 0.23 and thickness 1.5 mm, commercial aluminium sheet with

emissivity of 0.09 and thickness 1.5 mm and PETB film (polyethylene mixed with 5% TiO_2 and 2% $BaSO_4$) UV stabilized.

From all the three surfaces being tested, the highest collection was in the PETB units (19.4 mm) followed by galvanized iron (15.6 mm) and aluminium- 9 mm *(Sharan, 2011)*.

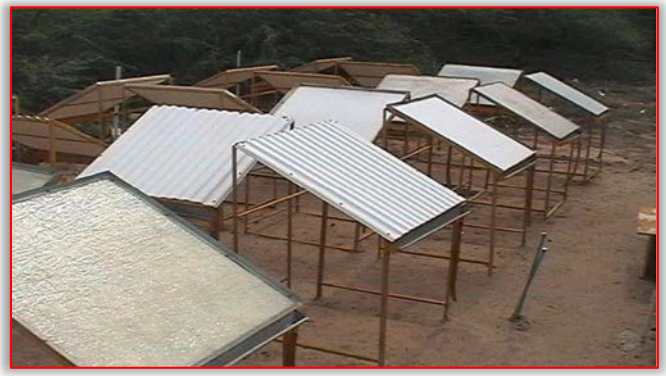

Figure 5. Different types of condenser surfaces (Sharan, 2011)

Active condensers typically require electrically powered compressors or vacuum pumps and the quantity of water harvested in directly related to the input energy *(Hasilaet al, 2020)*.

Compared to radiative condensers, active condensers are more efficient, with daily yields proven to be considerably higher *(Khalil et al, 2016)*.

The company Roots Up introduced a multifunctional greenhouse that allows farmers to grow food and collect water, named Ecodome. The greenhouse is an affordable technology that accumulates sufficient water reserves to provide year-round irrigation.

Figure 6. Ecodome-Dew Collector greenhouse (https://rootsup.com)

The greenhouse serves multiple purposes to suit different climatic conditions. It is designed to efficiently capture dew. The dome-like greenhouse is activated when temperatures increase in the noon sun, causing water to evaporate and rise. With the humidity contained, the top point of the structure catches this evaporation before it's able to escape into the atmosphere. As night falls, the greenhouse top is then opened by pulling the ropes attached to the latch, exposing the collected droplets to cool air. Those droplets then cool and condense, falling into a storage cistern. The collected water can then be used for watering plants. This system can be repeated each day, allowing plants to thrive while excess moisture is captured and saved for future use.

The Airdrop irrigation concept is a low-tech design that uses the simple process of condensation to harvest water from the air. Utilizing a turbine intake system, air is channeled underground through a network of piping that quickly cools the air to soil temperature. This process creates an environment of 100-percent humidity, from which water is then harvested. The collected water is stored in an underground tank, ready to be pumped out via sub-surface drip irrigation hosing. The Airdrop design also features an LCD screen displaying water levels, pressure strength, solar battery life and system health.

Figure 7. Airdrop irrigation design *(https://coolhunting.com/tech/airdrop)*

In 2016, INMA Bucharest developed the project "Intelligent technological system of condensation irrigation in greenhouses and solariums" which is intended for vegetable farms, especially those in areas threatened by desertification, to achieve a substantial saving of irrigation water. The field of use of the experimental model is the irrigation of vegetable crops in the open field or in protected environments (greenhouses, solariums), by capitalizing on the humidity in the soil and air, at a minimum installed energy power.

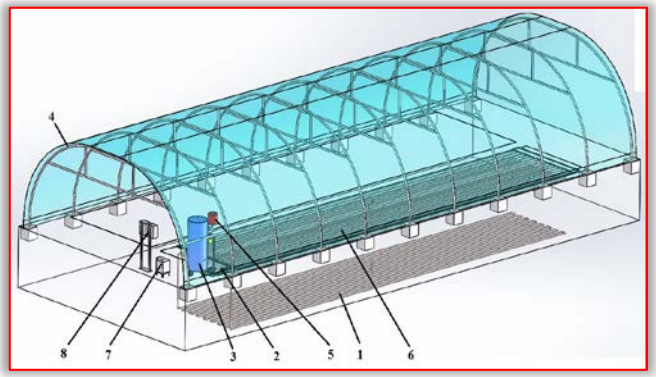

Figure 8. INMA's Intelligent technological system of condensation irrigation in greenhouses and solariums (Marin et al, 2017)

1-Temperature optimization installation in the area of plant roots; 2- Circulation pump; 3- Cold water tank; 4-Solarium with gothic vertical walls; 5- Expansion vessel; 6- Condensing system with copper pipes or with PHD pipes; 7- Water cooler; 8- Automation system

The system contains a condensing installation designed from a network with pipes, in version I of copper or in version II

of PHD, mounted in a closed loop, which by recirculating the cold water inside them combined with the high relative humidity and the air temperature inside the solarium will use water resulting from condensation for the irrigation of the vegetable crop.

CONCLUSIONS

This study presented methods of collecting air humidity for the purpose of valorization for crop irrigation. According to the forms of airborne water, the atmospheric water-harvesting technologies can be divided into two categories: fog water collection and dew water collection.

Studies have shown that fog and dew harvesting is feasible in terms of water quantity, water quality, and economy. Researchers have demonstrated that atmospheric humidity collectors can be used for collecting water and use it for irrigation. It recommended that collection be made at various locations and times, since both water quantity and water quality are variable in time and space.

Water harvesting is a technology that has greatly evolve in the past decades but challenges remain to be optimized for efficiency and to ensure the delivery of water with a quality appropriate to its end use.

Acknowledgement

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EVALUATION OF THE EFFECTS OF HEAT ON THE HARDNESS AND COMPRESSIVE STRENGTH OF SLAG CEMENT CONCRETE

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Abstract: This study investigates the thermal resistance ability of slag cement concrete. Heat from fire changes the physical, chemical and mechanical properties of concrete. Given the decisive role of thermal resistance in the operation and performance of concrete structures, it is necessary to evaluate the effect of heat on the performance of slag cement concrete. In this study, compression and hardness tests were carried out to examine the thermal resistance of slag concrete. Concrete cubes were prepared and cured for 28 days after which the samples were subjected to varying temperatures of 100, 150, 200, 250 and 300°C at 30, 45 and 60 minutes and the change in their hardness and compressive strengths were measured and compared with that of ordinary Portland cement concrete. The result of the experiment shows that the loss in strength was 0.45% at 100°C, 1.75% at 150°C, 2.67% at 200°C, 5.98 at 250°C and 12.04% at 300°C, the hardness was found to be increasing from 100 to 150°C but decreased with higher temperatures. But Normal concrete losses over 20% of its compressive strength at 300°C. This implies that higher temperatures exert adverse effects on the strength of concrete. From the results, it was observed that below the temperature of 250°C the concrete did not lost significant strength however, from 250°C and above, there was a significant loss of strength. The results show that slag concrete has slightly higher thermal resistance ability and as such can be suitable even in industrial areas.

Keywords: Effects, Heat, Compressive Strength, Hardness, Slag Cement, Concrete

INTRODUCTION

Any construction work requires a few materials, for example, solid, steel, block, stone, glass, mud, mud, wood e.t.c. Notwithstanding, the cement concrete remains the major construction material utilized by construction companies. The expanding requirement for cement concrete construction has had a natural effect including around 7 percent offer of CO_2 outflows to the environment [1,7]. One answer for environmental friendly concrete production is to utilize Slag Cement Concrete which is delivered by blending Ground Granular Blast Furnace Slag (GGBS) with Portland Cement or through the expansion of clinkers to GGBS.

Fire reaction of cement auxiliary individuals is reliant on the thermal, mechanical, and deformation properties of cement concrete. These properties vary considerably with temperature and furthermore depend upon the composition, characteristics of concrete batch mix and heating rate and other natural or environmental conditions

Fire is a standout amongst the riskiest phenomena that a structure might experience during its lifetime. The performance of normal concrete at high temperatures has extensively been investigated and its characteristics have been well-established [2-3].

The decrease of quality of ordinary cement because of physical and chemical changes in the microstructure of cement is caused by changes in hydration products. By raising the temperature, a lessening in the compressive strength of concrete will occur. Up to 300°C, fine splits are seen on the concrete surface. At temperatures over 400°C, calcium hydroxide (CaOH2) is decomposed to different items. Calcium silicate gel (C-S-H) as the significant segment of cement paste and the fundamental factor affecting the quality of cement is disintegrated at 600°C. With deterioration of hydration products at 800 °C concrete totally loosed its compressive quality. The aim of this study is to investigate the thermal capacity of blast furnace slag cement after heating at 100, 150, 200, 250, and 300°C.

Stress-strain reaction of essential materials at elevated temperatures, tensile strength, compressive strength and modulus of elasticity are the main mechanical characteristics that ascertain the fire performance of members of reinforced concrete.

Compressive strength of concrete at high temperature is of primary enthusiasm in fire safety design.

At ambient temperature, the compressive strength of concrete is a function of aggregated type and size, admixture types, water-cement ratio, aggregate-paste interface transition zone, type of stress and curing conditions. At elevated temperature, concrete compressive strength is significantly affected by binder in batch mix (fly ash, slag and silica fume), rate of heating and room temperature strength. While concrete mechanical properties are thoroughly researched, there is significant paucity of research with respect to the thermal properties of cement concrete at high temperature. Thus, a research gap that needs to be filled. The strength degradation in HSC is not consistent and there are significant variations in strength reduction, as established by various authors.

MATERIALS AND METHODS

— Materials

The materials used for this work were, well graded sand obtained at the University of Ibadan, the coarse aggregates

used was granite obtained at a quarry plant in Ibadan While the binder used was slag cement prepared by blending 50% of GGBS and OPC.

— Methods

Preparation of Sample

Slag was obtained from the Prism Steel Company Ikirun, the slag was crushed and grounded into powdered form which was used to prepared the binder. The binder used for this work was prepared by blending 50% of GGBS with Ordinary Portland Cement. The fine aggregates and the cement were thoroughly mixed on non-absorbent surface until the mixture was properly blended giving a uniform colour after which coarse aggregates was added with cement and fine aggregate until the coarse aggregate was uniformly distributed throughout the batch. Water was added and mixed until the concrete appears to be homogeneous and of the desired consistency.

Compressive and Hardness Test

The moulds were thoroughly cleaned and greased with oil to aid removal of formwork, the concrete was filled in the molds in layers approximately 5cm thick and each layer was compacted with not less than 35strokes per layer using a tamping rod, the top surface was leveled and smoothen it with a trowel. The test specimens were stored in moist air for 24 hours and after this period the specimens were removed from the moulds and submerge in a clean fresh water for 28 days. The specimen was removed from water after specified curing time (28 days) and wipe out excess water from the surface, 3 cubes were selected and crushed with the compression testing machine and the crushing load was recorded. A rebound harmer was used to test the hardness of the concrete.

After testing for 28 days strength, some concrete samples were selected and then heated at various time intervals of 30 minutes, 45 minutes and 1 hour to a varying temperature of 100, 150, 200, 250 and 300°C and the same procedure for cube test was carried out to determine the effects of the compressive strength of the concrete. In each case the compressive strength of the concrete was calculated and hardness of the concrete was determining by rebound harmer method to evaluate the effects of temperature on the concrete hardness.

Calculations for Compressive Strength of Concrete

To calculate the compressive strength of the samples, the maximum load was divided by the cross-sectional area (average) of the sample.

- Size of the cube = 10cm x10cmx10cm
- Area of the specimen (calculated from the mean size of the specimen) = 100cm^2
- Maximum load applied in tones would be converted to Newton.
- Compressive strength = (Load (P) in N/Area (A) in mm^2)

where P is the maximum load at which the specimen fails while A is the area of the cube. Characteristic compressive strength (f_{ck}) at 28 days was calculated and recorded.

RESULTS AND DISCUSSION

Table 1.1. Compression Test Result

Temperature (0C)	Time (Minutes)	Sample A Load (kN)	Sample B Load (kN)	Sample C Load (kN)	Average Load (kN)
0^{0}C	00	250.30	252.01	251.38	251.23
100^{0}C	30	250.30	250.75	250.48	250.51
	45	250.85	250.3	251.38	250.44
	60	251.38	250.85	250.96	250.06
150^{0}C	30	249.27	247.16	247.69	248.04
	45	248.74	247.69	247.67	248.03
	60	246.11	247.68	246.64	246.81
200^{0}C	30	247.67	246.11	245.06	246.28
	45	247.16	244.04	242.95	244.72
	60	245.01	245.58	242.95	244.51
250^{0}C	30	241.89	244.50	243.58	243.32
	45	240.00	240.00	241.50	240.50
	60	238.10	235.00	235.50	236.2
300^{0}C	30	240.10	241.20	239.50	240.27
	45	235.20	237.60	234.90	235.90
	60	222.39	221.00	220.60	220.60

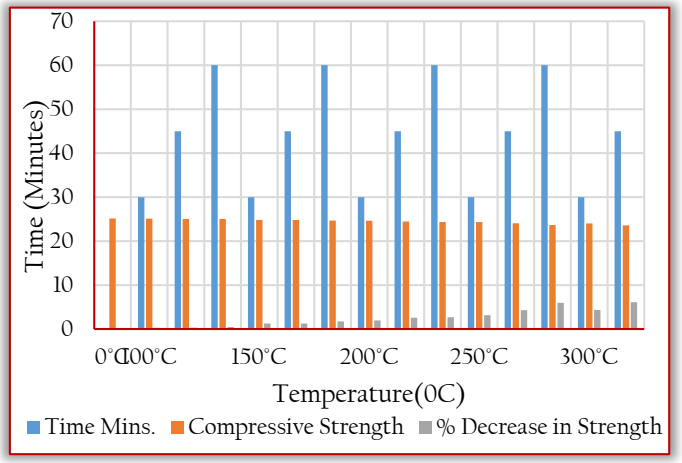

Figure 1.0. Compressive Strength Result at Varying Temperatures and Time with Percentage Decrease.

Table 1.2 Hardness Test Result

Temperature (0C)	Time (Minutes)	Sample A	Crushing Sample B	Load kN Sample C	Average
0^{0}C	00	25.00	25.00	26.00	25.33
100^{0}C	30	34.00	33.50	33.00	33.50
	45	34.00	33.50	34.50	34.00
	60	35.50	35.00	34.50	35.00
150^{0}C	30	36.50	37.00	36.50	36.67
	45	37.50	37.00	36.50	37.00
	60	36.50	36.50	37.50	36.83
200^{0}C	30	35.50	36.50	36.00	36.00
	45	35.50	36.00	35.00	35.50
	60	35.00	35.00	35.50	35.17
250^{0}C	30	36.50	37.00	36.50	36.83
	45	36.00	36.50	36.00	36.17
	60	35.50	36.50	35.50	35.67
300^{0}C	30	35.00	35.50	34.60	35.03
	45	34.50	34.50	35.00	34.67
	60	34.00	33.50	33.20	33.57

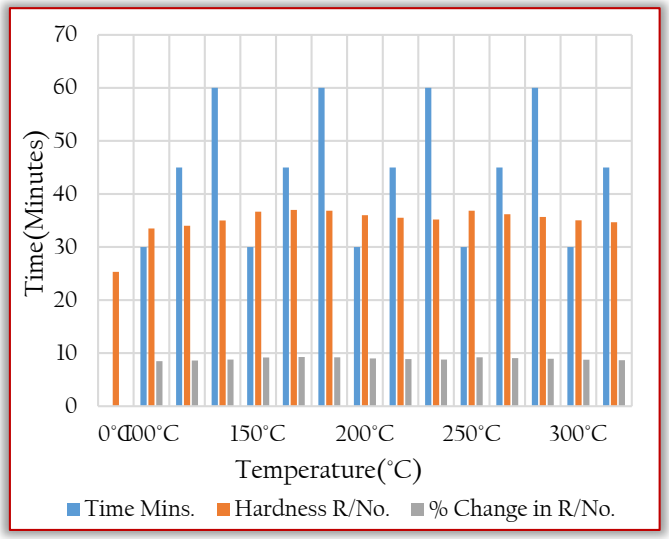

Figure 1.1. Hardness Result with Varying Temperature and Time

Table 1.3. Summary of Results

Temperature °C	Time Mins.	Compressive Strength	% Decrease in Strength	Hardness R/No.	% Change in R/No.
0°C		25.13	00	25.33	0
100°C	30	25.12	0.29	33.50	8.49
	45	25.05	0.31	34.00	8.61
	60	25.04	0.45	35.00	8.79
150°C	30	24.80	1.27	36.67	9.16
	45	24.80	1.27	37.00	9.25
	60	24.68	1.75	36.83	9.21
200°C	30	24.63	1.97	36.00	9.00
	45	24.47	2.59	35.50	8.87
	60	24.33	2.67	35.17	8.79
250°C	30	24.33	3.15	36.83	9.20
	45	24.05	4.27	36.17	9.04
	60	23.67	5.98	35.67	8.92
300°C	30	24.03	4.36	35.03	8.76
	45	23.59	6.10	34.67	8.67
	60	22.10	12.04	33.57	8.39

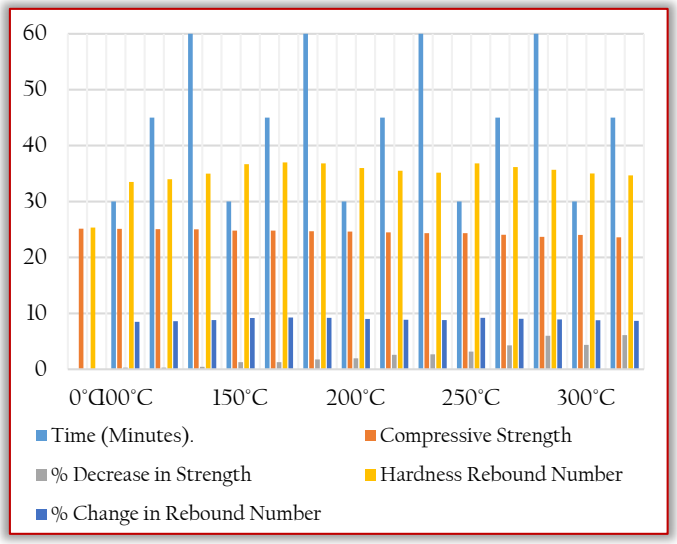

Figure 1.3. Comparative Summary of Compressive Strength and Hardness Results

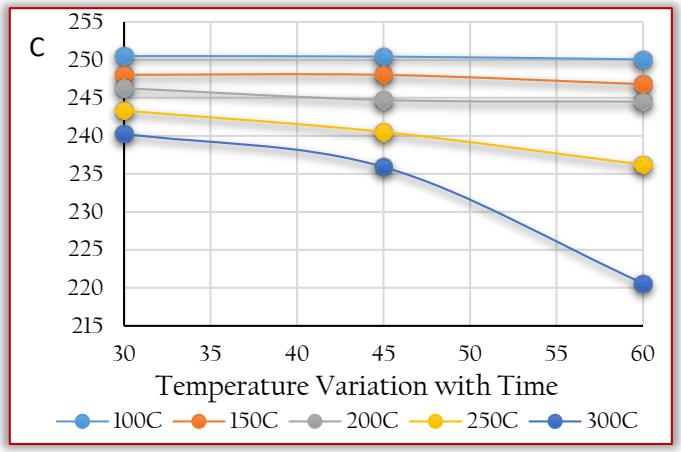

Figure 1.4. Compression Test Graph (Crushing Load Against Time)

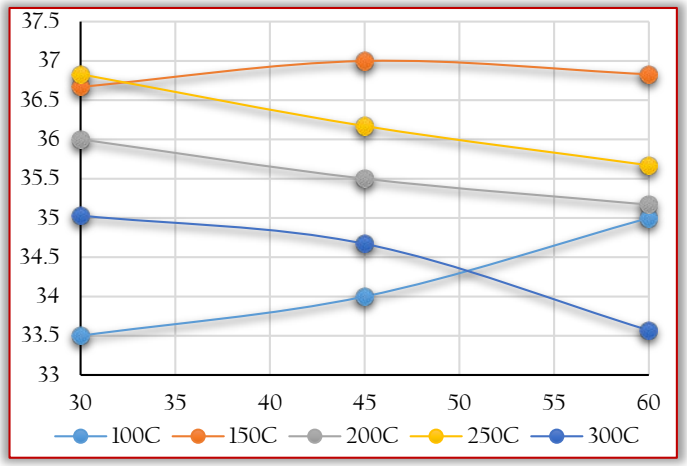

Figure 1.5. Hardness Test Graph (Rebound Number Against Time)

DISCUSSION

From the results above, it was observed the concrete losses it compressive strength with increase in temperature. It was also observed that the maximum loss in compressive strength was 0.45% at 100°C, 1.75% at 150°C, 2.67% at 200°C, 5.98 at 250°C and 12.04% at 300°C. Normal concrete losses over 20% of its compressive and bond strength at 300°C [2]. This shows that Slag cement has a slight higher resistance to heat attack than Ordinary Portland Cement in terms of both compressive and bond strength. The hardness of concrete was found to be increasing from a temperature of 100°C to 150°C, the peak hardness was observed at 150°C at a heating time of 45 minutes but beyond this, the hardness of the concrete began to drop. This shows that moisture content also has effects on concrete hardness. Between a temperatures of 100°C to 150°C, the effects of temperature were more of drying effects but beyond this point concrete began to lose it hardness.

Higher temperatures exert adverse effects on the strength of concrete. The compressive strength of slag cement concrete was found to be considerably higher than Portland cement as already established by other researchers. Slag concrete has good workability. When concrete is heated gradually, loss of weight appears to take place in two stages, namely, the drying stage, evaporation of water from large capillaries and

voids will take place. At the dehydration stage, which occurs loss of non-evaporated water from the gel pores and small capillary pores will take place. Considerable concrete shrinkage is accompanied at this stage. It was noted that at 100^{0}C, the specimen weighed 2437g but 2168g at 300^{0}C.

In the view of [5] the lower strength of the saturated concrete is attributed to the disjoining pressure within the cement paste.

In compression tests it has been observed that air-dried specimens show 20-25% higher strength than corresponding specimens tested in a saturated condition [5]. For an oven-dried specimen, the increase in strength is of the order 10-15%. This increase in strength appears to be reversible as subsequent re-saturation will return the concrete to its original strength at water saturated condition [8]. The effect of moisture content on strength becomes an important consideration when testing drilled cores.

According to [8] it may have something to do with the change in the structure of the C-S-H on drying, or it may simply represent a change in the cohesion and internal friction using a microscopic scale; a lubricating effect created by moisture causing the slipping of particles more easily in shear. The lesser in the compressive strength of wet concrete is as a result of the internal pore pressure produced by the applied load.

CONCLUSION AND RECOMMENDATIONS

From the results above, it was observed that concrete losses it compressive strength with increase in temperature. It was also observed that the maximum loss in compressive strength was 0.45% at 100^{0}C, 1.75% at 150^{0}C, 2.67% at 200^{0}C, 5.98 at 250^{0}C and 12.04% at 300^{0}C. It was observed that from a temperature of 100-200^{0}C, there was no significant effects of temperature on the compressive strength of the slag concrete. Above a temperature of 200^{0}C and up to 300^{0}C the effects of temperature on the compressive strength of concrete became significance. At 250^{0}C (5.98%) at 60 minutes but was still not significance at 30 and 45 minutes (3.15-4.27%), but at 300^{0}C, a significance effect was noticed from 45 minutes to be 6.10%. The higher the temperature, the lesser the compressive strength. It was also observed that the time interval at which the concrete was subjected to heat has a significant influence on the concrete strength, the more the concrete stays under heat, the lesser the strength. Slag Cement concrete has slightly higher but approximately the same thermal resistance ability as compared to ordinary portland cement.

Hence, Structural design for fire safety for ordinary portland cement can be applicable for slag cement. Furthermore, a manual of structural design for fire safety should be developed for slag cement.

This study has revealed that while concrete mechanical properties are thoroughly researched, there is significant paucity of research with respect to the thermal properties of slag cement concrete at high temperature. It is recommended that more research should be carried out on the thermal properties of slag cement concrete.

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APPLICATION OF MOLECULAR MARKER crtRB1-3′TE IN MAIZE SELECTION

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Abstract: Biosynthesis of β-carotene in maize is influenced by three key genes: psy, lcyE and, at most, crtRB1. The gene of β-carotene hydroxylase 1 (crtRB1) on marker crtRB1-3′TE has three allelic states: 296 bp, 296 + 875 bp and 543 bp. The aim of the study was to identify perspective inbreds of Ukrainian selection with a favourable for the accumulation of β-carotene allele of marker crtRB1-3′TE (543 bp). The study revealed DK315MV and DK267MV inbreds, which had the 543 bp allele in the homozygous state and are recommended as parental forms for breeding programs for increased β-carotene content in mature grain.

Keywords: Zea mays L., molecular marker, β-carotene hydroxylase 1, MAS

INTRODUCTION

Insufficient micronutrients in food lead to serious human health problems. This mainly applies to zinc, iron, vitamin C and vitamin A *(Frano et al, 2014; Muthusamy et al, 2014)*. By involving methods of biofortification of major crops using integrated approaches to plant breeding and genomics, it is possible to solve the problem of vitamin deficiency, in particular, provitamin A *(Ashokkumar et al,2020)*.

More than three million children in developing countries are affected by xerophthalmia, and 250,000 to 500,000 people become blind each year due to vitamin A deficiency (VAD) *(Food and Agriculture Organization, 2017)*.

Vitamin A manifests itself in the human body as a multifunctional compound. It is involved in a number of important physiological processes such as: visual acuity, cell growth and differentiation, embryogenesis and immune response. Vitamin A in the human body forms a number of structurally similar substances: retinol, dehydroretinol, retinal, retinoic acid, esters of these substances and their spatial isomers. Directly retinoic acid is actively involved in the regulation of the transcription process *(Klyuchnikov et al, 2007; Shamitova and Viktorovich, 2019)*.

Maize is one of the most important cereals, which is able to accumulate a significant amount of carotenoids in the endosperm. Thus, improving the balance of micronutrients in maize grain through biofortification is an economically and socially reasonable way to overcome vitamin and micronutrient deficiencies, including VAD *(Yan et al., 2010; Pixley et al., 2012)*.

Currently, about 750 carotenoids have been found from natural sources. Depending on the presence or absence of oxygen in their structure, carotenoids are divided into oxygen-containing xanthophylls and oxygen-free carotenes *(Nimishi et al., 2016)*. Carotenoids are rather unstable compounds that degrade under the action of high temperatures, light and oxygen *(Boon et al., 2010; Stephen et al., 2016)*. Some carotenes, such as α-carotene, β-carotene and β-cryptoxanthin, can be converted into vitamin A. However, only β-carotene is able to form 2 molecules of vitamin A per 1 original molecule, while α-carotene and β-cryptoxanthin only one *(Berman et al., 2017; Harjes et al., 2008)*.

In addition to vitamin activity, carotenoids in plant cells play an important role as auxiliary pigments for photosynthesis, promote protection against photooxidation, attract pollinating insects, etc. *(Sagare et al., 2018)*.

The synthesis of β-carotene in plants begins with the starting substance – geranylgeranyl-pyrophosphate -GGPP (Figure 1).

With the participation of phytoene synthase encoded by gene *psy*1 (*y*1) two GGPP molecules condense into one phytoene molecule. Plants containing *psy*lgene produce carotenoids in both endosperm and leaves. The allelic construction of *psy*1 gene significantly affects the colour of maize grain, with a corresponding accumulation of carotenoids in it. Genotypes *Y1Y1* and *Y1y1* produce yellow kernels as a result of carotenoid accumulation, while genotype *y1y1* forms white grains that do not contain carotenoids *(Fu et al., 2013; Sagare et al., 2018)*.

Through a series of intermediate reactions from GGPP, lycopene is formed - the first coloured substance. At this point, the path of carotenoid biosynthesis branches into α-branch and β-branch (fig. 1). In symmetrical cyclization, lycopene forms a molecule with two β-rings (producing first γ-carotene and then β-carotene) under the action of lycopene β-cyclase (LCYB) at both ends of the linear lycopene. In asymmetric cyclization under the action of the enzyme lycopene ε-cyclase (LCYE), lycopene is converted into δ-carotene – a precursor of α-carotene, zeinoxanthin and lutein. Decreasing level of LCYE reduces the formation

of substances from the branch of α-carotene in favour of substances of the branch of β-carotene *(Bai et al., 2009; Harjes et al., 2008; Pixley et al., 2012)*.

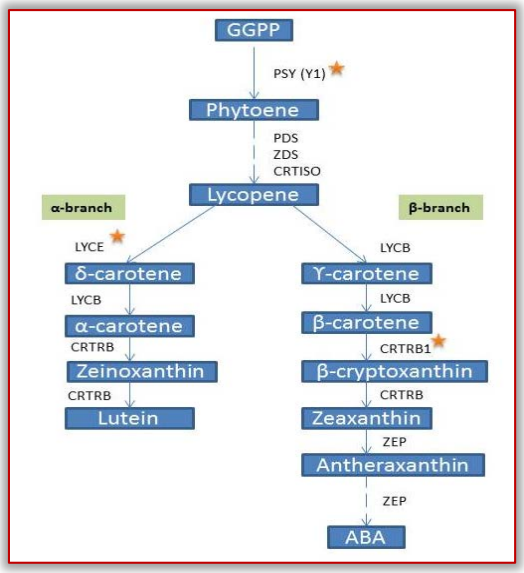

Figure 1. Simplified carotenoid biosynthetic pathway in plants (Berman et al., 2017; Harjes et al., 2008; Thanh, 2019; with modifications)
Enzymatic reactions are represented by arrows, dashed lines – multiple enzymatic steps. Compounds: GGPP – Geranylgeranylpyrophosphate; ABA – Abscisic acid. Enzymes: PSY – phytoene synthase; PDS – phytoene desaturase; ZDS – zetacarotene desaturase; CRTISO – carotene isomerase; LCYE – lycopene ε-cyclase; LCYB – lycopene β-cyclase; CRTRB – carotene hydroxylase enzymes, which include ε-carotene hydroxylase and β-carotene hydroxylases; CRTRB1 – β-carotene hydroxylase 1; ZEP – zeaxanthin epoxidase; Major genes for carotenoid biosynthesis pathway

Another key gene in carotenoid synthesis is gene of β-carotene hydroxylase 1 (*crt*RB1; also known as HYD), which causes hydroxylation of α-carotene and β-carotene into lutein and zeaxanthin, respectively. Hydroxylation of carotenes reduces the content of carotenoids with the properties of provitamin A, thereby increasing the content of non-provitamin xanthophylls *(Sagare et al., 2018)*. As a result, maize endosperm accumulates a significant amount of other substances, primarily zeaxanthin through two hydroxylation reactions of β-carotene. Blocking these hydroxylation reactions can increase the content of β-carotene in the endosperm of mature maize grain *(Berman et al., 2017; Muthusamy et al., 2015)*. Thus, mutations in the β-carotene hydroxylase gene (*crt*RB1) in maize lead to a slowing of the transition of β-carotene into β-cryptoxanthin during grain ripening and, consequently, to an increase in the content of β-carotene in mature grain.

Berman et al. (2017) used RNA interference to silence genes *Zmcrt*RB1 and *Zmcrt*RB3 genes encoding two β-carotene hydroxylases on both branches. *Zmcrt*RB1 regulates the transition of β-carotene to β-cryptoxanthin while *Zmcrt*RB3 mostly hydroxylates β-ring of α-carotene. The content of β-carotene in the endosperm increased significantly in all hybrids in which *Zmcrt*RB1 was silenced, regardless of whether *Zmcrt*RB3 was silenced.

A significant increase in β-carotene in maize grain was achieved using genetic engineering technologies *(Aluru et al., 2008; Naqvi et al., 2009; Simkin, 2019; Zhu et al., 2009)*. Most gene modifications concerned key carotenogenesis genes: *psy*1, *pds*, *zds*, *lcy*B, *lcy*E, *crt*RB1 *(Thanh, 2019)*. Transgenic maize plants with the high-value carotenoid astaxanthin in grain endosperm were obtained by combining overexpression of the *psy* gene for enhanced carotenoid production and silencing the *lcy*E gene to direct more precursors to the β-branch *(Farré et al., 2016)*. *Zhu et al. (2008)* used the construction containing five genes of carotenoid biosynthesis for the genetic transformation of maize genome: maize gene of phytoene syntase 1, gene of phytoene desaturase from *Pantoea ananatis*, genes of lycopene cyclase and carotene hydroxylase from *Gentiana lutea*, and the carotene ketolase gene of *Paracoccus*.The authors generated transgenic maize plants with extraordinary levels of β-carotene (57.35 μg / g DW) and other carotenoids, including complex mixtures of hydroxycarotenes and ketocarotenes.

Among the considered mechanisms of influence on the accumulation of β-carotene in maize grain, marker-assisted selection (MAS) on the allelic state of key carotenoid biosynthesis genes is important for practical use. *Yan et al. (2010)* found that provitamin A content was 5.2-fold higher with favourable alleles of markers *crt*RB1-5′TE and *crt*RB1-3′TE in gene *crt*RB 1. According to *Babu et al. (2013)* and *Muthusamy et al. (2014)* the presence of a favourable *crt*RB1-3′TE allele increases the concentration of β-carotene by 2–10 times regardless of the genetic constitution of gene *lcy*E.

According to *Muthusamy et al. (2014)* polymorphism of gene *crt*RB1 due to transposon insertion in exon 6 led to the appearance of three alleles of this gene in maize, namely allele 1 (543 bp; without TE insert), allele 2 (296 bp + 875 bp; with an insert TE - 325 bp) and allele 3 (296 bp + 1221 bp + 1880 bp; with an insert TE - 1250 bp), which were associated with changes in the accumulation of β-carotene *(Muthusamy et al., 2014)*. The presence of allele 1 of the *crt*RB1 gene (hereinafter allele 1) is favourable and increases the level of β-carotene in the grain, while alleles 2 and 3 are unfavourable for the accumulation of this substance.

The aim of our study was to determine the allelic status of the gene of β-carotene hydroxylase 1 by the molecular marker *crt*RB1-3'TE in maize inbreds of Ukrainian and world selection.

MATERIAL AND METHOD

The materials for the study were perspective inbreds of maize (*Zea mays* L.) of Ukrainian selection DK3044, DK267MV and DK315MV and well-known inbreds of world selection P354 and A188. DNA was isolated from seedlings by CTAB method *(Murray and Thompson, 1980)*. For each inbred, the DNA of one seedling and DNA of a mixture of 5 seedlings picked over the average sample were analyzed. Evaluation of the β-carotene hydroxylase 1 gene by the allelic

state of the marker *crt*RB1-3′TE was performed by PCR with primers according to *Yan et al. (2010)*:

F: ACACCACATGGACAAGTTCG, R1: ACACTCTGGCCCATGAA CAC and R2: ACAGCAATACAGGGGACCAG.

The reaction mixture of 20 µl contained: 2.0 µl of DNA of the test lines, 1.0 µl of each primer, 2.0 µl of a mixture of deoxyribonucleotides (dNTP), 2.0 µl of Green Taq Buffer, 0.15 µl of Taq polymerase and 10.85 µl deionized water.

PCR was performed according to *Safawo et al. (2010)* in two repetitions under the following conditions: initial denaturation - at a temperature of 94 ° C for 5 minutes; then 40 cycles, which included stages such as denaturation (at 94 ° C for 1 min.), annealing of primers (at 60 ° C for 1 min.) and elongation (at 72 ° C for 1 min.). The final elongation was performed at 72 ° C for 5 minutes, the cooling phase was carried out at + 10 ° C. Visualization of the amplification products after electrophoretic separation in 1% agarose gel was performed with ethidium bromide (0.5 µg / ml) in a tris-borate buffer system at 120 V for 60 min, using a GelDocTM instrument (BioRad). For the *crt*RB1-3′TE marker, bands of 543 bp (favourable allele), 296 bp and 296 + 875 bp (unfavourable alleles) were expected. As reference samples in the determination of allelic state of *crt*RB1-3′TE marker we used DNA of inbreds A619 and B73 which had been tested with the same primers earlier and were regarded in our laboratory for identification of allele 1 (A619 – 543 bp) – and allele 2 (B73 – 296 bp).

RESULTS

The investigated maize inbreds differed in grain colour at full ripeness (fig.2), from white (A188) to yellow of different intensity (DK3044, DK267MV, DK315MV) and even reddish-brown (P354). The given variation may be connected with the different content of colouring substances from the group of carotenoids and xanthophylls.

Figure 2. The grain of maize investigated inbreds DK3044, DK267MV, DK315MV, P354 and A188 varies in colour

The results of PCR-analysis testified that the reference DNA sample of inbred A619 proved the presence of a band in 543 bp that was the instance of allele 1 of *crt*RB1-3′TE marker (fig. 3). The reference DNA sample of inbred B73 demonstrated the allelic status of the same marker as 296 bp that was the evidence of allele 2.

All maize investigated inbreeds revealed only one variant of the *crt*RB1-3′TE marker, both in DNA samples from one plant and in DNA samples from mixture of five plants. This fact indicates the homozygosity of the studied inbreeds on this marker. In DK267MV and DK315MV allele 1 of *crt*RB1-3′TE marker (543 bp) was identified, while in P354, DK3044 and A188 – allele 2 (296 bp). Allele 3 (296 + 875 bp) among the studied samples were not detected.

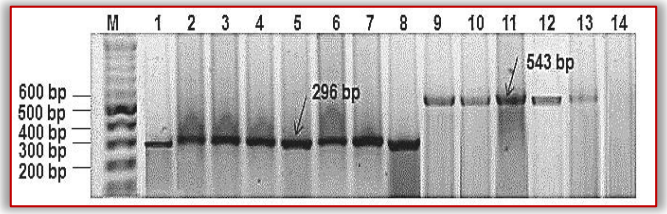

Figure 3. Electrophoreogram of maize DNA amplification products by molecular marker crtRB1-3′TE of the gene of β-carotene hydroxylase 1

M - molecular weight marker with a step of 100 bp; 1 - inbred P354 (DNA of one plant); 2 - inbred P354 (DNA mixture of five plants); 3 - inbred DK3044 (DNA of one plant); 4 - inbred DK3044 (DNA mixture of five plants); 5 - inbred A188 (DNA from one plant); 6, 7 - inbred A188 (DNA mixture of five plants), 8 - control for allele 2 (296 bp) – inbred B73; 9 – inbred DK267MV (DNA of one plant); 10 - inbred DK267MV (mixture of DNA of five plants); 11 - inbred DK315MV (DNA of one plant); 12 - inbred DK315MV (DNA mixture of five plants); 13 - control for allele 1 (543 bp) – inbred A619; 14 - control without DNA

CONCLUSIONS

Among the five investigated maize lines DK3044, DK267MB, DK315MB, P354 and A188, a polymorphism was detected by the *crt*RB1-3′TE marker in the gene of β-carotene hydroxylase 1. This polymorphism is occurred due to the presence of two alleles, which after PCR with appropriate primers ensure the appearance of two bands in 543 bp and 296 bp. All studied inbreds were homozygous for this marker. Favourable allele of the marker *crt*RB1-3′TE 543 bp has been identified in the inbreds of Ukrainian selection DK267MB and DK315MB. So these in breds are recommended for use as parental forms for the creation of maize hybrids with increased content of β-carotene in mature grain.

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Technological Platform", in Bucharest, ROMANIA, 30 October, 2020.

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INCREASING THE QUALITY OF SEPARATION IN THE PHASE OF PREPARATION OF OIL FOR TRANSPORT

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Abstract: In order to prepare oil for transport, it is necessary to extract certain amounts of dissolved gas, water and various impurities. The extraction of gas from oil begins already in the reservoir, and then in the well due to the reduction of pressure (depression). Further separation of the gas and liquid phases is achieved by the following technological processes: separation of oil (separation of gas and liquid), dehydration of oil (separation of formation water and oil) and storage of oil. Oil transport is divided into domestic transport, which includes the phase of oil collection and preparation as well as the main transport, defined as the transport of oil from dispatch stations to the central dispatch station. The final phase of transport is transport from shipping stations to refineries. There are one-stage and multi-stage separation. In order for the oil to be better prepared for transport, it is necessary to increase the quality of the separation itself, and this is achieved by installing additional equipment, such as: defoamers, vortex breakers, coalescers and droplet traps, droplet traps in emulsions and sand washing system. In order to achieve the highest possible quality of separation, it is necessary to understand that in the entire system of internal collection of oil and gas, collection stations have the most important role. Their task is to collect the produced oil and gas from a certain number of wells, to separate the gas from the oil, individually and collectively measure these fluids, store the oil and transport it to the loading station, as well as transport the gas to the compressor station and other consumers.
Keywords: petroleum, transport, oil separation, oil dehydration, oil storage, single stage separation, multistage separation, defoamers, vortex breakers, coalescers and droplet traps, droplet traps in emulsions, sand washing system, collection station

INTRODUCTION

Oil and gas collection means the entire transport of oil and gas in the field, from wells to loading stations. The collection systems used for this can be divided into two large groups: open and closed. Due to their great advantages, only closed oil and gas collection systems are used everywhere in the world today. The companions of oil are natural gases (methane, ethane, propane, butane), it can be accompanied by nitrogen, hydrogen, carbon monoxide, salt water (it has a corrosive effect).

Crude oil must be refined before use. According to its chemical composition, oil is a mixture of hydrocarbons such as alkanes, cycloalkanes, aromatic hydrocarbons, benzene. Some oils also contain iron, nickel and molybdenum (catalytic poisons). The mixture of oil and gas extracted from the wells is collected at appropriate places (measuring or collection stations) where the separation of the liquid and gas phases is performed. How many collection or measuring stations there will be in the oil field will be determined, first of all, by the distance and number of wells, as well as the amount of wells.

After separation and measurement, the gas is shipped through a low-pressure gas pipeline and subjected to transport preparation processes. The liquid remaining after separation contains not only oil as the desired product of separation, but also a certain amount of water produced. In the last few years, world demand for crude oil has increased by approximately 38% - from 9.55 x 106 m^3 / day in 1985, to 13.13 x 106 m^3 / day in 2004 [4]. To the amount of oil produced is accompanied by an equal or greater amount of free water and bound water, which forms emulsions with the oil.

MATERIAL AND METHODS

— Oil collection

Collection, as one of the basic functions of the collection – transport system, implies the transport of liquids from individual wells to a common location where preparation for transport is performed.

The fluid is transported either by individual oil pipelines or collector pipeline systems, which mostly depends on factors such as reservoir size, terrain morphology, well layout and number, as well as the dynamic pressure at the wellhead. The mixture of oil and gas extracted from wells should be directed to measuring or collection stations where the separation of gas and liquid phases is performed, measurement of extracted quantities of oil and oil gas and oil storage if it is a collection station.

There are three systems for collecting a mixture of oil and gas:

a) individual system,
b) a system of separate pipelines or multiple measuring or collecting stations, and
c) collection system [6].

— Oil preparation

In order to prepare oil for transport, it is necessary to extract certain amounts of dissolved gas and water. Extraction of gas from oil begins already in the reservoir, and then in the well due to the reduction of pressure. Further separation of gas and liquid phases is achieved by the following technological processes:

a) separation of oil (separation of gas and liquid),
b) dehydration of oil (separation of formation water and oil) and
c) oil storage [6].

— **Oil separation**

The final phase of separation takes place in separators at a certain constant pressure and constant temperature. Separators are devices that separate gas and liquid (oil + water).

The efficiency of the separator is determined by the phase equilibrium, which is primarily influenced by the pressure, temperature and composition of the mixture, but also by the appropriate structural elements within the separator that ensure better separation of the liquid and gas phases.

Extraction of gas from oil takes place in two ways, basically following the same ways of separation that occur in the reservoir itself. The first way is the contact separation of the gas phase, during which the liquid and gas phases are in constant contact. The process is caused by a change in pressure and temperature, and the significance of this separation is the molecular action in which a part of medium-heavy hydrocarbons passes from the liquid to the gas phase.

Another way is the differential separation of the gas phase in which there is no contact of two separate phases, but the formed gas phase is completely separated from the process. The simplified principle of such separation is based on the gradual reduction of pressure, during which gas is released while the entire amount of medium and heavy hydrocarbons remains in the liquid.

In the separator, there is a one-stage separation and a multi-stage separation. One-stage separation is identical to the contact separation of gas and liquid phase due to the fact that it is performed in a closed system with a change in temperature and maintaining a constant pressure. Separation is performed in one or more parallel separators within which there is no change in phase equilibrium. Multi-stage separation takes place in line-mounted separators with different pressures and different temperatures [3].

— **One-stage separation**

The process takes place in one or more parallel separators in which the same pressure and temperature prevail. The phases that are formed in such conditions are in contact all the time of separation and there is no change in the composition of the mixture. Therefore, the conditions under which phase equilibrium occurs remain the same throughout the process. The characteristic of such separation is the increased amount of gas phase enriched with heavier hydrocarbon components.

Thus, one-stage separation can be equated with flash gas degassing from oil. Since this is the only, and thus the last stage of separation, oil and gas are sent from the separator for further processing, storage or transport [5].

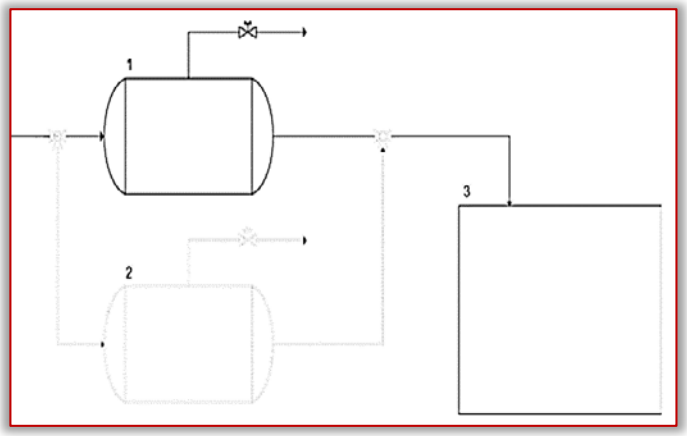

Figure 1. Composition of equipment in single-stage separation [5]
1-separator;
2-possible additional separator for larger quantities of mixture;
3-tank.

— **Multistage separation**

In this case, the mixture obtained from the well goes through several stages of separation. Each stage is characterized by a different, lower value of pressure and temperature at which gas escapes from the oil (Figure 2). Since gas and liquid phases are formed inside the separator, one of them is separated from the process. The rest of the mixture, which is no longer of the same composition, is then sent to the next stage of separation.

The procedure is repeated as many times as the degree is defined by the process. Several comparative separators can be used for each stage, depending on the amount of fluid. This principle can be equated with the differential or gradual release of gas from oil. The characteristic of this method is reflected in the gradual reduction of the pressure of the mixture and finally in a larger amount of the obtained liquid phase [4].

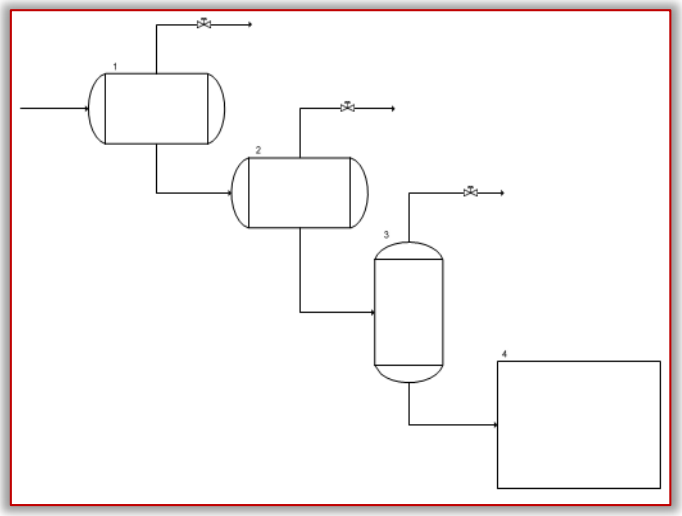

Figure 2. Composition of equipment in multi-stage separation [5]
1-high pressure;
2-medium pressure;
3-low pressure separator;
4-tank.

— **Separator equipment**

The purpose of installation is to increase the functionality of the separator and the efficiency of the separation process. The standard equipment of the separator is considered to be: input separator elements and coalescers, which are installed regardless of the shape of the separator or the number of phases that are separated.

The rest of the equipment is added as needed, most often in horizontal separators because they are more flexible in terms of available space and possible layout, and at the same time they are more susceptible to negative phenomena that occur during operation.

When choosing the equipment, the most attention should be paid to the characteristics of the mixture and the design of the separator, because in case of non-compliance, the opposite effect can occur, that is disruption of the separator [3].

— **Defoamers**

The foaming of the surface layer of oil, except when the mixture enters the separator, also occurs when gas bubbles are released from the oil. This problem complicates the separation and automatic regulation of the process, and can be solved by adding chemicals at the inlet to the separator or, more simply, by mechanical defoamers. It is a series of parallel, obliquely placed longitudinal plates that cover the height to which the oil-gas boundary moves.

By passing the foamed mixture through the separator, there is contact between the formed foam bubbles and the plate, breaking the bubbles into droplets which then merge into the accumulation section of the separator [9].

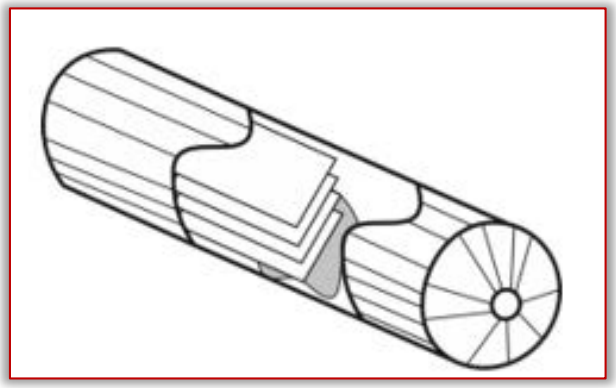

Figure 3. Scheme of defoamers in the separator [1]

Barriers to neutralize the shock waves of the mixture

The formation of waves inside the separator can occur due to the pulsating inflow of the mixture or in the case when the separator is placed on the platform. Since this phenomenon negatively affects the separation process, it is necessary to install appropriate elements that will reduce their effect. This is especially true for long horizontal separators in which the action of waves is most pronounced.

Barriers are placed vertically on the flow of liquid, so that they cover the accumulation section from the bottom to above the barrier or so that they cover only the profile of a certain height around the level of the barrier. The picture shows a full profile partition with perforations [8].

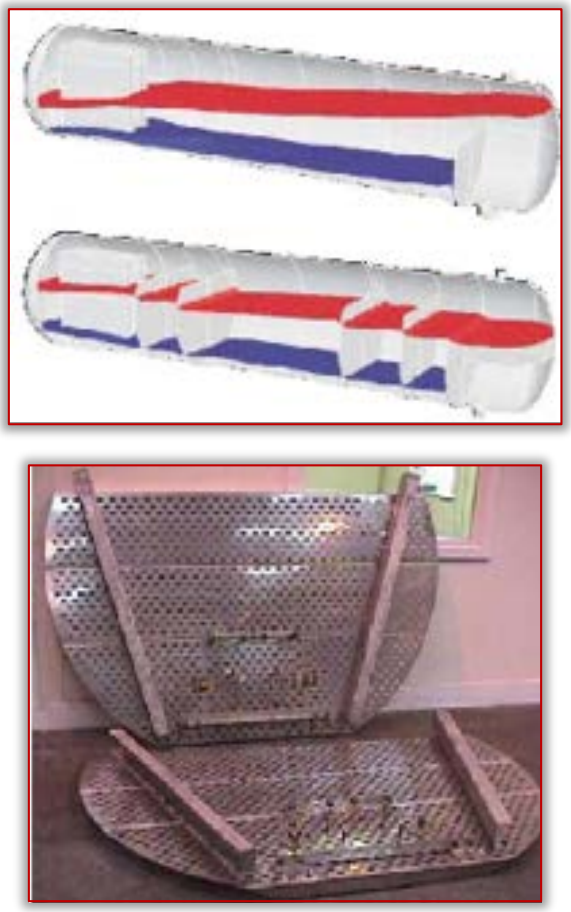

Figure 4. Influence of barriers on liquid rolling and barrier appearance [1]

— **Vortex breakers**

Vortices are the result of poorly designed drains from the separator, and they occur when the valve is opened and liquid is drained from the separator.

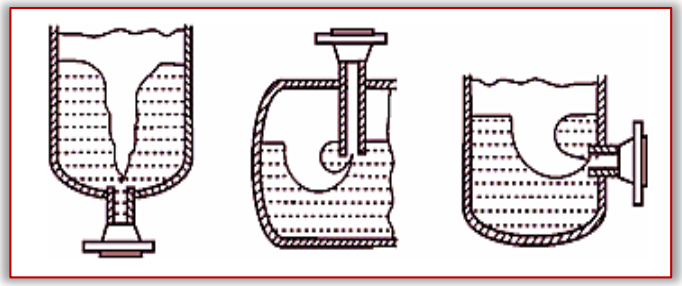

Figure 5. Possible places of vortex formation in the separator [1]

Their formation in two-phase separators leads to the withdrawal of gas into the oil outlet line, which, in addition to the unwanted presence of gas in the outlet line, also leads to a large drop in pressure in the separator. In three-phase separators, the layer of oil and water also mixes, which in the end can mean the suction of oil into the outlet line during the discharge of water. Prevention of vortex formation is achieved by installing the so-called Vortex breaker. These are various plate elements that are placed above the outlet or elements that are installed in the outlet pipe (Figure 6) [7].

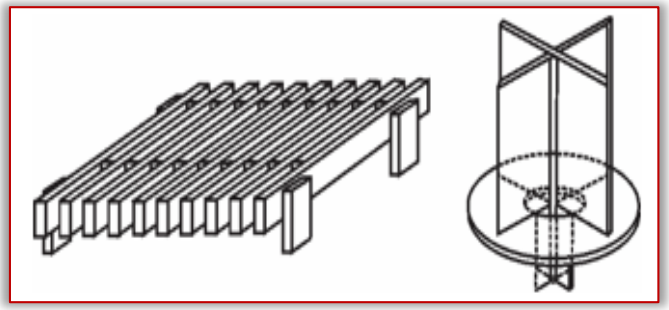

Figure 6. Basic types of vortex "breakers" [1]

— **Coalescers and droplet catchers**

The quality of separation is also reflected in the content of the liquid phase in the gas leaving the process. The lower that concentration, the more successful the process. Therefore, different elements are used to separate the droplets from the gas stream. The size of the droplets present in the gas phase depends on the method of formation, and their diameters can range from 0.1 to 5000 μm.

The smallest are those droplets that occur as a consequence of gas condensation (size from 0.1 to 5 μm). If the larger droplets are separated into smaller ones by mechanical action, for example when the mixture passes through a semi-open valve at high speeds, then their size can range from 10 to 200 μm. Finally, the largest droplets are formed during direct expulsion from the liquid due to the entry of fluid of uneven inflow, hitting the barriers and the like [2].

Figure 7. Droplet catchers of various constructions [2]

— **Sand washing system**

Accumulated sand can occupy a fairly large part of the separator after some time, which can lead to disruption of the separator. This problem is especially pronounced with horizontal separators, and an alternative to manual cleaning of the bottom can be the installation of a flushing system. The system consists of manifolds and nozzles arranged to cover the bottom of the separator.

For rinsing, water obtained from the process whose output speed from the nozzle (5 m / s) causes the movement of the sand layer towards the drainage openings through which the mixture of water and sand exits the separator is most often used. During the rinsing, the separation process does not need to be stopped. The system can act selectively, so that it rinses only the desired part or the entire separator, and with the appropriate equipment it can be fully automated. The figure shows the rinsing system and rinsing technique [2].

Figure 8. Flushing system [2]

— **Horizontal separators**

Horizontal separators are a very common choice in practice where they are mostly used as three-phase separators. Their construction results in the following advantages over other types of separators:

- the possibility of processing a large amount of mixture,
- possibility of processing the mixture subject to pulsating inflow and foaming,
- the possibility of processing the mixture with a medium and high proportion of the gas phase - due to the large contact area between the liquid and gas phases, and the large length are suitable for quality gas separation and
- for the same supplies, they are cheaper than upright separators (simpler construction).

The disadvantages of horizontal separators are:

- are not suitable for processing mixtures with a high proportion of solid particles. After some time, the precipitated solid particles cover the bottom of the separator along its entire length, which makes their removal more difficult.
- the possibility of gas re-entering the liquid,
- require more storage space and are not suitable for installation in places such as platforms,
- uneven flow of the mixture into the separator can cause level control errors and even cause accidental interruption of the process, which is a problem in the automation of the separator [6].

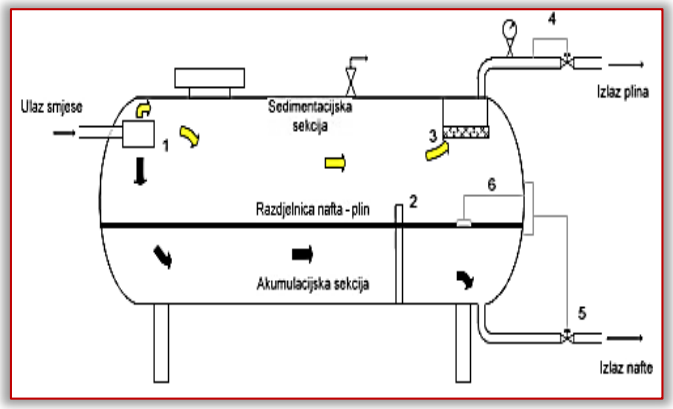

Figure 9. Scheme of horizontal separator [6]
1-entrance partition;
2-partition;
3-droplet catcher;
4-pressure regulator and gas discharge valve;
5-oil drain valve;
6-level regulator (float).

— **Upright separators**

In practice, in addition to horizontal, separators of upright construction can usually be seen. Upright separators are mainly used for processing a small amount of mixture with a small proportion of gas phase. They are a good choice if solid particles are present in the produced fluid, because the bottom of the separator is concave in shape, due to which the precipitate comes out of the separator together with the liquid or a separate drainage hole can be placed below the liquid outlet line. The probability of gas re-entry is small, because the phases after the initial separation have the opposite direction of movement. The height of the separator ensures easier and more reliable placement of control parts for automatic regulation, and due to the construction, they are mounted in places where space is limited [6].

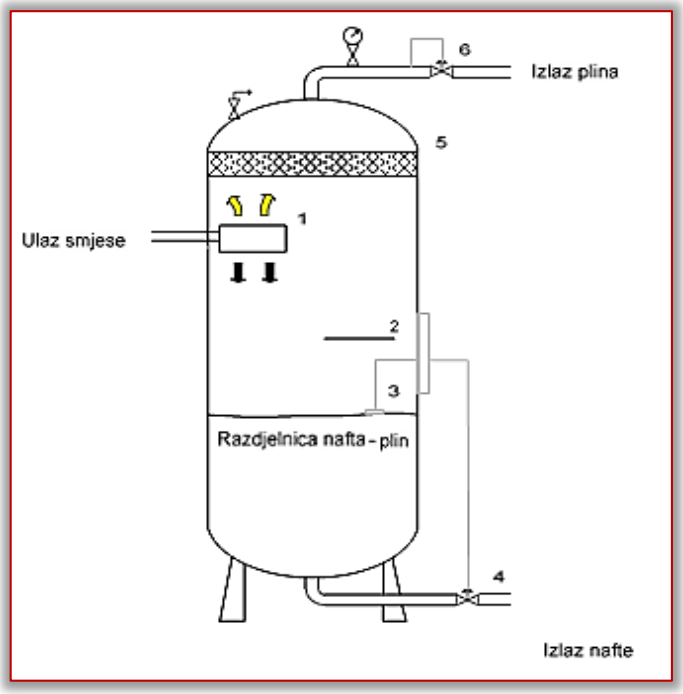

Figure 10. Schematic of an upright two-phase separator [6]

RESULTS AND DISCUSSION

— **The first stage of separation**

In two-phase separators, the liquid and gas phases are separated. The gas phase is discharged from two-phase separators into the drip tray (separator of a small amount of residual oil into gas), and the liquid phase (water / oil) with a small amount of the remaining gas phase into a three-phase separator.

Table 1.Characteristics of vertical separators [6]

Name of equipment	Operating parameters				Project parameters			
	Amount of fluid/oil Q, [m3/h]	Amount of gas Q, [m3/h]	Pressure p, [bar]	Temperature t, [oC]	Amount of fluid/oil Q, [m3/h]	Amount of gas Q, [m3/h]	Pressure p, [bar]	Temperature t, [oC]
Vertical two – phase measuring separator	6,79	21,65	2 – 4	55	52	471 0,36	8,5	60
Vertical two – phase collective	6,79	21,65	2 – 4	40 – 50	52	471 0,36	8,5	60
Gas dripper	-	43,3	2 – 4	10 – 40	52	471 0,36	8,5	60

From the drip tray, the gas phase is directed to the boiler room, to the boiler, for the production of hot process water, and the excess is burned on a torch.

Table 2. Parameters of horizontal three-phase separator [6]

Name of equipment	Operating parameters				Project parameters			
	Amount of fluid/oil Q, [m3/h]	Amount of gas Q, [m3/h]	Pressure p, [bar]	Temperature t, [oC]	Amount of fluid/oil Q, [m3/h]	Amount of gas Q, [m3/h]	Pressure p, [bar]	Temperature t, [oC]
Horizontal three – phase separator	13,58	43,3	2 – 3	40 – 50	533,33	4357 0,83	4	60

When guiding the separator, it is necessary to maintain the level of the water phase at the highest possible value, in order to prolong the retention time in the separator. Extending the retention time of the aqueous emulsion and passing through the existing coalescing device in the second chamber of the separator, contributes to the desired reduction of the proportion of dispersed oil droplets in the aqueous emulsion that is increasing the efficiency of the device.

CONCLUSION

Separators are steel vessels under a certain pressure. They can be located at a well, measuring or collection station where the acceptance and processing of hydrocarbon mixtures from nearby production wells is performed. Their main task is to separate the mixture into gas and liquid phase. The type of separator to be used depends first of all on the properties and quantity of the mixture, as well as the working pressure. In the process of selecting the separator, future changes in the properties of the produced fluid should be taken into account, in order to avoid problems in the operation of the separator and possible additional costs at a later stage of production.

Note:
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RESEARCH ON THE USE OF PHOTOVOLTAIC SYSTEMS TO POWER OFF-ROAD ELECTRIC TRACTORS

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Abstract: Recent technological development aimed on increasing performances of electrochemical energy storage systems and the new advances of electric motors have created new opportunities for electrical equipment manufacturers in terms of autonomy, performance and stability over time. The development of electric vehicles reported a strong expansion lately, however, electric farm tractors operating in off-road environment are not yet considered interesting for the large equipment manufacturers, due to their high-power operation needs and the small capacity that energy storage systems may offer. One interesting research direction is assessing the opportunity of charging batteries directly in the field, using photovoltaic sources, located close to the land to be processed. In order to address to this important electric vehicle limitation, new technology is needed which will allow the batteries to be charged during the operation of the vehicle, or to recharge near the area to be tilled. Some models are equipped with replaceable battery pack, which can be easily sent on charging and replaced with a new fully charged pack. The present paper examines the ground area requirements for the installation of a photovoltaic station, designed to charge a prototype tractor model, produced by INMA Bucharest.
Keywords: electric tractor, photovoltaic charging, efficiency

INTRODUCTION

Agriculture tractors are usually diesel-powered, contributing to fossil energy consumption, global warming, air pollution and in many cases to soil and groundwater pollution, caused by fuel leakages (*Xue Ji., 2013, Zhang X., 2011*).
Recent technological development aimed on increasing performances of electrochemical energy storage systems and the new advances of electric motors have created new opportunities for electrical equipment manufacturers in terms of autonomy, performance and stability over time.
This has allowed car manufacturers to assume major challenges regarding the development of electric or hybrid vehicles, successfully replacing engines that use fossil fuels, while maintaining high levels of performance.
A segment that has not yet managed to reach high levels of performance, allowing to switch from diesel to electrical operation is the industrial field of heavy-duty vehicles, especially those used for agriculture *(Mocera F., and Soma A., 2020)*.
One of the most important problems encountered by electric tractors is that they cannot have the energy density close to a diesel model, that is required to do long, hard work in the field. Performing activities that need high power such as plowing or transporting heavy trailers would drain power much faster from the battery pack (*Choi, S.C. et. al, 2014, Finesso R., 2014, Vaidya A.S., 2019*). Refueling batteries is easily done in the case of agricultural machinery that operates around the farm, but in the case of an agricultural tractor working in the field, returning to the farm is not a viable option.
Diesel equipment can operate continuously for many hours and time periods could be extended even more if will provide a fuel tank in the vicinity of the working area, while battery life is dictated by total loads. In case of heavy loads, the disadvantage of recharging at short intervals, may turn this option into an uneconomical choice.
In order to address to this important electric vehicle limitation, new technology is needed which will allow the batteries to be charged during the operation of the vehicle, or to recharge near the area to be tilled. Some models are equipped with replaceable battery pack, which can be easily sent on charging and replaced with a new fully charged pack. This option of quick exchanging the battery pack minimizes the time required to park the tractor for recharging the batteries, but it also raises negative issues regarding battery management, and increase the cost of having a spare battery pack.
However, when evaluating high energy consuming equipment as agricultural tractors, must consider several other aspects, including the impact on the environment, reducing global fossil fuel consumption as well as CO2 emissions reduction.
While on grid field chargers may provide with the electricity required to manage an agricultural electrical vehicle, many studies agree that the installation of autonomous photovoltaic systems capable of charging batteries should be considered in order to further facilitate the use of renewable energy and to minimize CO2 emissions (*McFadzean B., 2017; Adegbohun Fe., 2019, Dai Q., 2019, Nenciu F., 2014*). This option would be very useful in cases where the electricity network is at a far distance from the plots that are being processed or when the electrical network does not allow overloaded local electricity grids, giving additional flexibility.
There has been little research on local power systems used to recharge batteries used on agricultural tractors, that is why the present article aims to discuss the main problems posed

by the large-scale operation of electric tractors, and to objectively evaluate the main ways of feeding electric tractors.

We will first explore how off grid photovoltaic systems can contribute to the charging of electric vehicles according to different geographical positioning, given the maximum potential depending on the location on the globe, the relief forms and the seasonal variations.

Additional benefits could, for instance, be less and additional grid flexibility. Our previous research studies (Matache et. all, 2020), highlighted that in the case of specific tillage that require high operating powers, the electric tractor performing time must be improved in order to be able to process a larger number of hectares.

The method of installing photovoltaic panels directly on the roof of the machine can show some improvement, but has a relative low impact due to the small installation area. Therefore, our objective was to identify and calculate the characteristics of an autonomous photovoltaic system, providing the electric powered supply directly in the field, without the need for changing the batteries.

MATERIALS AND METHODS

Our goal was to determine the area in square meters to be covered by panels to ensure the needed electricity consumption. In order to achieve our goal, the first phase was to determine the power requirements of the electric tractor for various agricultural works, afterwards had to estimate the charging potential of the photovoltaic panels and then calculate the insolation potential depending on the climatic conditions of the area.

In order to calculate the power needed for the plowing process, we have tested an experimental model of agricultural electric tractor, designed by INMA Bucharest (figure 1). The 28,8 Kw electric tractor was equipped with a 17.28 kWh Li-Io battery pack and an ORION battery management system (BMS) that allowed recording the instantaneous power consumption during works. The tractor was equipped with a mechanical transmission of 8 forward gears / reverse shift, having a speed range between 1.71 km/h - 26 km/h and a nominal rotational speed of the electric motor of 2350 s^{-1}.

An agricultural electric tractor performs intense and complex tasks during its lifetime, being challenging to quantify all the activities and the solutions designed to perform its specific purpose.

In evaluating electric tractors we had to split the total power output among different potential loads, such as wheel loads, hydraulic tools, mechanical tools, power take off, etc., activities that are also dependent on the agricultural processes that are carried out (ploughing, cultivation, sowing, roller packing, harrowing). In figure 2, one can observe the power needed for the operation of an agricultural tractor, depending on the main soil tillage performed, under external conditions close to optimal from which we can draw the conclusion that the most intense activity is represented by plowing (*Tong F., 2015*). Although there are many variables that could change the absolute power levels, it is observed that the percentage do not suffer significant changes.

Figure 1. INMA Bucharest electric tractor prototype

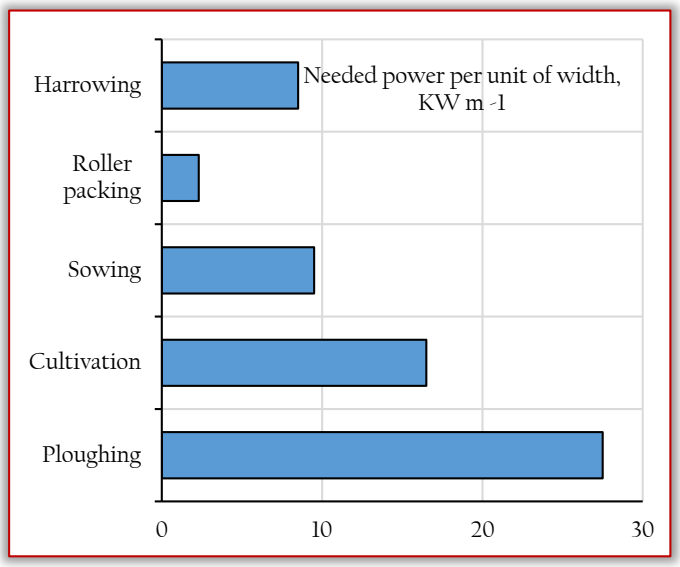

Figure 2. Electric tractor power needed for the main soil works, depending on the main soil tillage performed

RESULTS

The activities performed by the electric tractor were continuously monitored using a QuantumX 1615 amplifier data acquisition system to test the draft force, while a 10 kN hydraulic cylinder have been managed to measure in INMA Bucharest laboratory the strain gauges for the draft force.

Have been then calculated the drawbar power Pd and the electric power input Pe for the electric motor using the equations 1, 2, followed by the determination of power delivery efficiency of the system during plowing (PDE) equation 3. The drawbar power Pd (W), have been calculated as the as the product between mean draft force Fd (W) and actual working speed va (m/s).

$$Pd=Fdva, [W] \quad (1)$$

Electric power input has been calculated as product between battery voltage U, (W) and battery current I, (A), as follows:

$$Pe=UI , [W] \quad (2)$$

$$PDE = Pd/PE \quad (3)$$

The plowing process was performed at 3 depths (0.1 m; 0.15 m and 0.2 m), the results of the activity of the electric tractor during the plowing process are being presented in Table 1.

Table 1. INMA Prototype electric tractor testing

No.	Working depth a, m	Actual working speed va, m/s	Mean draft force Fd, N	Drawbar power Pd, W	Electric power input Pe, Kw
1	0.1	0.50545	3822	1932	3
2	0.15	0.48895	5728	2801	5
3	0.2	0.4719	7527	3552	7
4	0.1	0.9988	3884	3879	8
5	0.15	0.9526	5801	5526	10
6	0.2	0.8954	7644	7013	13
7	0.1	1.4032	3926	5509	11
8	0.15	1.3392	5844	7826	14
9	0.2	1.2608	7789	9571	19

No.	Power delivery efficiency PDE	Tractor autonomy, h	Ploughing productivity, ha/h	Total ploughed surface, ha
1	0.55930	5.00	0.09	0.46
2	0.60964	3.76	0.09	0.33
3	0.48300	2.35	0.08	0.20
4	0.48858	2.18	0.18	0.39
5	0.56958	1.78	0.17	0.31
6	0.55647	1.37	0.17	0.23
7	0.47958	1.50	0.25	0.38
8	0.54217	1.20	0.24	0.29
9	0.49988	0.90	0.22	0.20

Unlike electric road vehicles, that are usually charged using local grid, off-road electric equipment needs more flexibility by adopting dedicated solar PV charging systems located closer to the working area.

In evaluating the feasibility of implementing a photovoltaic power supply system for powering off-road electric tractors, models have to be created to determine the relations of the electricity balance, financial consequences, CO2 emissions reductions, or grid interactions.

In countries that have increased irradiations levels all year long, the solar photovoltaic charged electric vehicles can be operated more effectively than in countries with a high variability of irradiation over the year.

The potential to produce electricity using energy generated by the Sun is complex and depends on variable factors.

An important aspect to be considered is the region characteristics when calculating the production capacity, taking into account the month in the year, when the specific agricultural activity takes place.

The measurement of average daily solar radiation that can be converted into energy is called Solar insolation and express the average daily kilowatt hours received per square meter in a day.

Insolation intensity levels on the globe have been measured, so that the annual estimations can be made by modeling the average data from the last 10 years, and then validate the future estimations using a pyranometer and a photovoltaic panel. Corrections are needed, given the discrepancies generated by climate change, shading areas or various other losses.

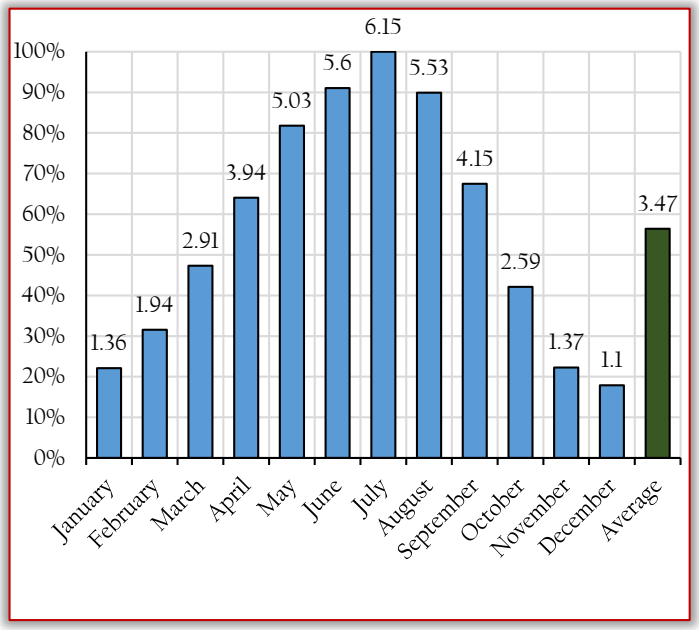

Figure 3. Insolation average levels in Bucharest using last 10 years estimations, in KWh/m2 per day, values that were validated using a pyranometer and a photovoltaic panel

Figure 3 shows that the months in which the activity of agricultural works is maximum coincides with the period in which the insolation in Romania is at high average levels. The chart also offers the possibility for the management to change the planning of some activities, which can be done in a longer margin of time, so as to benefit from the maximum potential generated by the panels.

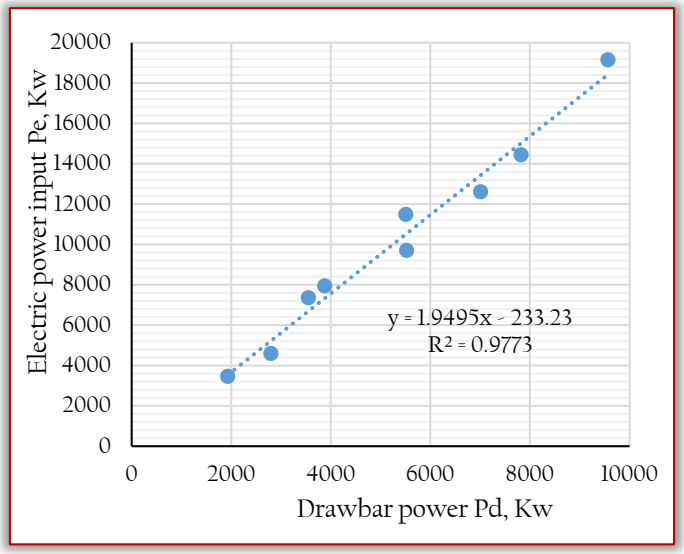

Figure 4. The determined electrical power

By interpolating the monitored values of drawbar power Pd, and Electric power input Pe, we can determine a dependency relationship between the two (Figure 4). This might be an important variable to determine electrical power, when knowing the drawbar power.

In order to estimate the energy required to perform various works with electric tractor prototype, we have used equation 4. The needed energy E (Kwh) represents the number of hours in which the tractor consumes that electric power. The energy generated in output of a photovoltaic system is dependent by a solar panel area (A, m²), a solar panel yield (r, %), annual average irradiation on tilted panels (H, kWh/m2.y), and performance ratio (PR, %). The performance ratio is a coefficient for losses that can occur such as: inverter losses, temperature losses, DC cables losses, AC cables losses, shadings losses, losses at weak radiation, losses due to dust, snow, etc.

$$E = A * r * H * PR, [Wh] \quad (4)$$

The energy required for the operation of an electric tractor varies greatly depending on the activity to be performed, some activities such as plowing requiring high power to operate, while some other activities such as spraying crops are not so demanding on energy requirements. The sizing of the photovoltaic power supply system must be made according to the activities to be performed with the electric tractor.

Considering that annual irradiation is dependent on the month of the year, with values between 496 kWh/m²_year and 2245 kWh/m²_year, a solar panel yield of 15%, a performance ratio of 0.73 and the total losses of 15 % with the site, technology, temperature, dust, etc., the photovoltaic panels areas variation depending on the produced energy can be seen in figure 5. Have been considered losses caused by temperature, above average (10%) because it is assumed that the power plant will be positioned close to the agricultural land where temperatures are very high.

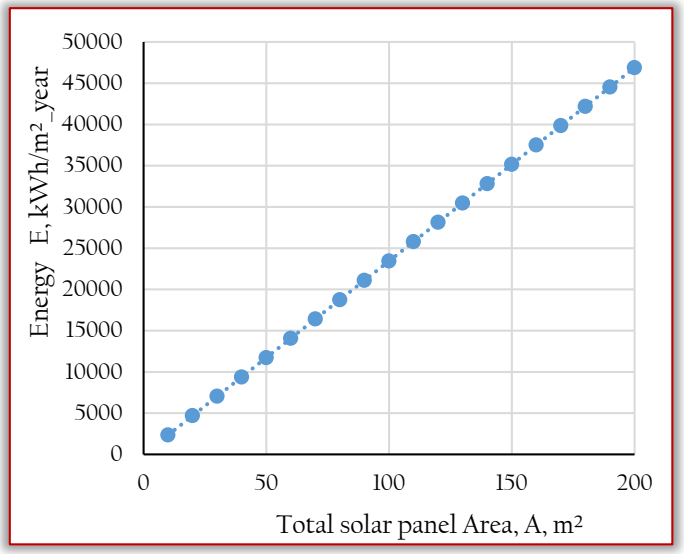

Figure 5. - The variation of the photovoltaic panels areas depending on the average produced energy

However, the graph might not be relevant enough, considering that the insolation is dependent on the seasons and the month of the year.

Therefore, have been calculated the variation of the areas needed to be covered by photovoltaic panels, depending on each month of the year and the annual average irradiation, (figure 6), which can be very important in the design of photovoltaic installations for powering electric tractors working off-road.

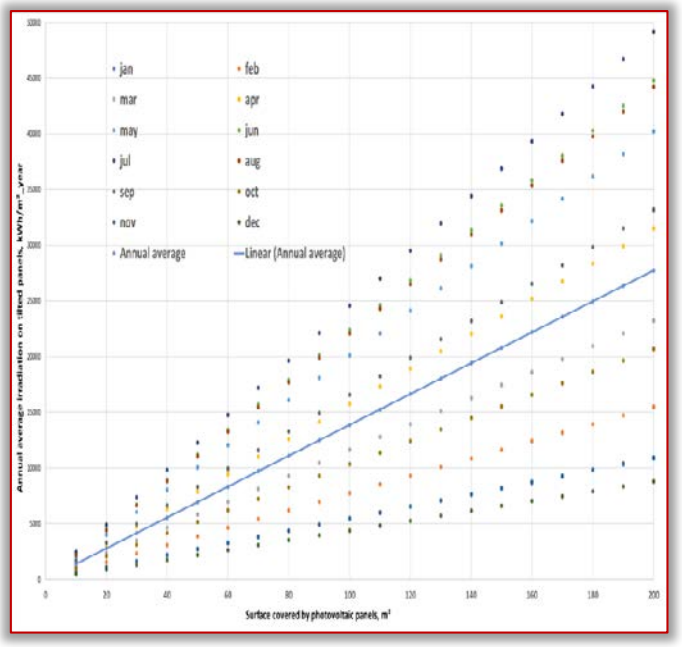

Figure 6. Variation of the total area needed to be covered by photovoltaic panels, depending on each month of the year and the annual average irradiation

CONCLUSIONS

In order to calculate the power needed of an electric tractor designed for off-road works we have been testing an experimental prototype, designed by INMA Bucharest, in different working conditions. The potential of photovoltaic energy production in Romania was then analyzed using both

statistical data and corrections by monitoring with a pyranometer.

The results were then used for analysis the variation of the total area needed to be covered by photovoltaic panels, depending on each month of the year and the annual average irradiation, useful element in evaluating the usefulness of installing an autonomous photovoltaic system, for powering tractors with off-road use.

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SOLAR POWER SYSTEMS AND DC TO AC INVERTERS

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Abstract: In this article solar power systems architecture along with the brief overview of the DC to AC inverters and their utilization as a power electronics device in solar photovoltaic systems is provided. The study provides details regarding the types of the inverters, single phase half bridge inverters, single phase full phase inverters and three phase inverters. As pulse width modulation (PWM) is widely used in inverters which works as a solar charge controllers so the principles of PWM along with carrier based and carrier less modulation techniques is also mentioned. A comprehensive simulation and implementation of a three phase PWM inverter in Simulink Matlab is also provided.
Keywords: Solar Power Systems, Inverters, Pulse width modulation, Smart grids, Control Strategies, Simulation Model

INTRODUCTION

The major sources of producing electricity in the world include fossil fuels and coals which are increasing the greenhouse gases (GHG) emissions. These GHG emissions are the main reason behind the climate change. As the population of world is increasing this is also resulting in increase in demand of the electricity as well. After the Paris agreement on climate change, the countries have decided to cap the carbon emissions up to certain levels and to reduce the production of the GHG gases by stop using conventional fossil fuels to produce electricity. One of the clean options was the Nuclear power but after the meltdown of the Fukushima Daiichi nuclear plant in Japan due to the tsunami caused by severe earthquake on March 2011 the governments around the world are now no more considering Nuclear as an option for environmental production of energy instead the only option for the clean energy production with the unlimited natural resources left is through the renewable energies [1]. The incentives provided by the governments is helping in more installations of solar power plants around the world at residential and commercial levels.

Therefore in order to achieve the targeted goals regarding climate change set by UNFCC [2] the increase in PV generation facilities can be play an important role. As there is abundance of sun and solar energy in the world so we can consider photovoltaic (PV) energy effect to be an important sustainable resource because of this the photovoltaic systems are widely used, as the source of electricity in urban and rural areas. In this study, solar power system types are discussed with the types and classifications of DC to AC inverters and their importance regarding the integration of DC solar power systems with the AC side of the utilities as well is discussed. Also in this paper using Matlab model simulation of the PWM inverters is discussed.

TYPES OF PHOTOVOLTAIC SYSTEM

The solar power systems can be branded into different types depending upon the electric production ability and according to the end user energy requirements.

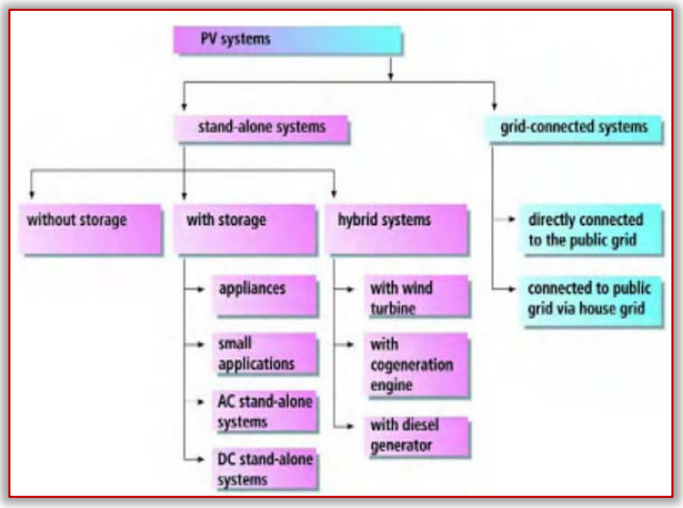

Figure 1. Types of PV systems source (The German Energy Society, Deutsche Gesellschaft für sonnenenergie (DGS LV Berlin BRB), 2008)

— Stand-alone systems

The other term used for standalone systems is "off-grid solar power systems" as they are commonly used in areas where grid or utility power is not available. These systems are independent of any other source of energy and the energy produced by sun is not only utilized during the day but access is stored in battery banks to be used when there is no sun available. These systems are used where supply of electricity is immediately required and with minimum price. The systems can be installed in shortest time periods and no hassle or rustle is needed like the provision of high transmission lines and the transformers. These systems are mostly being used in rural electrification projects and in remote areas where the grid is not available. The OFF-Grid solution is the solution in which you can simply live without the GRID and produce and use your own produced energy according to your requirements.

Following are the main components required for such kind of systems:

1. PV modules
2. Charge controllers
3. Battery bank

4. Load
5. Ac inverter for systems where alternate current is required at the loads

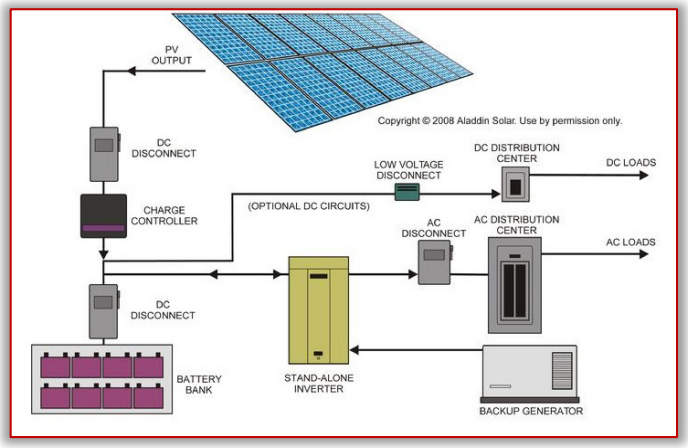

Figure 2. Schematic diagram of solar off grid system

— **Grid connected systems**

This is a solar power system which is linked to the utility grid. In unconnected systems (standalone systems) we need battery bank for energy storage but in grid connected systems the energy which is produced more than the requirement of end user is transported back to the utility grid to be used where there is shortage of energy. In grid-connected systems the community electricity grid is used as an energy store as well.

Many countries around the world prefer mostly solar PV systems to be connected to the utility grid because that helps their national grids is getting access energy from the solar systems, reduce production of cost of energy production by use of fossil fuels and in return the citizens with solar installations enjoy rebates. Feed-in tariff for production of solar electricity also helps the user to get back the initial investment on the system at the earliest.

The standard grid-connected PV systems are mostly made up of the following components:

1-PV modules/array

2-PV array combiner/junction box

1. 3-Direct current (DC) cabling
2. 4-Inverter
3. 5-AC cabling
4. 6-Meter cupboard with power distribution system, supply and feed meter, and electricity connection.

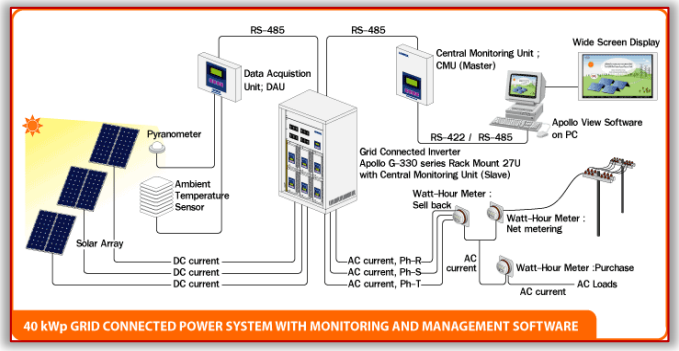

Figure 3. Grid connected PV system (source: http://www.leonics.com)

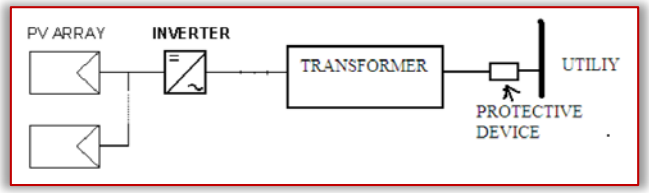

Figure 4. Block diagram Grid-Connected System

The use of transformers increases the ac output voltage when needed. Where there is no boost up of ac current required, transformer less designs are preferred. In order to prevent resistive power flow from utility to the solar system protective devices like under voltage relay, circuit breakers etc are installed.

Grid-connected photovoltaic (PV) energy is one of the fastest growing and most promising renewable energy sources in the world.

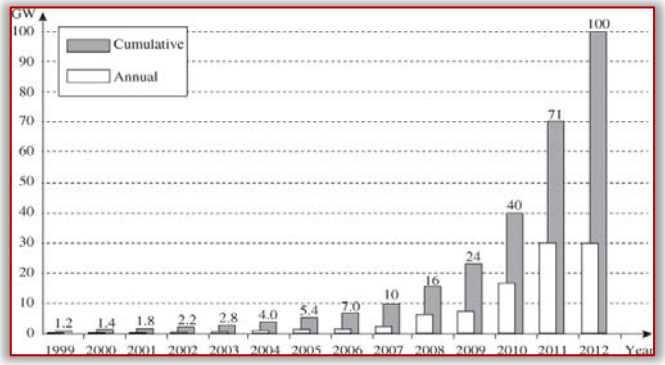

Figure 5: World annual and cumulative installed photovoltaic capacities Source: Abu-Rub, Malinowski, & Al-Haddad, 2014

According to London based research and consulting firm GlobalData, the global collective installed solar photovoltaic (PV) capacity would increase from 175.4 Gigawatts (GW) in 2014 to approximately 223.2GW in 2015. According to GlobalData's recent report China is considered as the major market leader in PV installations with about 17.6 GW in 2015.

— **Hybrid Systems**

In hybrid systems the required output power is obtained by two or more different power generating sources. A system can be hybridinized by combining different renewable energy sources such solar and wind together to get the common output required by the end user. Solar power system can also be joined together with the diesel generator in areas where there is needed and for better performance. The main aim of hybridization is to get the stable output from the renewable energy sources and cater for fluctuations caused because of the environmental conditions while using solar and wind generation.

Sometimes hybrid systems are also known as "Integrated renewable energy systems".

Hybrid systems are generally planned to meet the peak demand when they run in combination with conventional power generation systems. For example in case of wind and PV hybrid power plant these two separate systems share a single inverter for power conversion and a single storage facility depending upon the case of grid connected system[3].

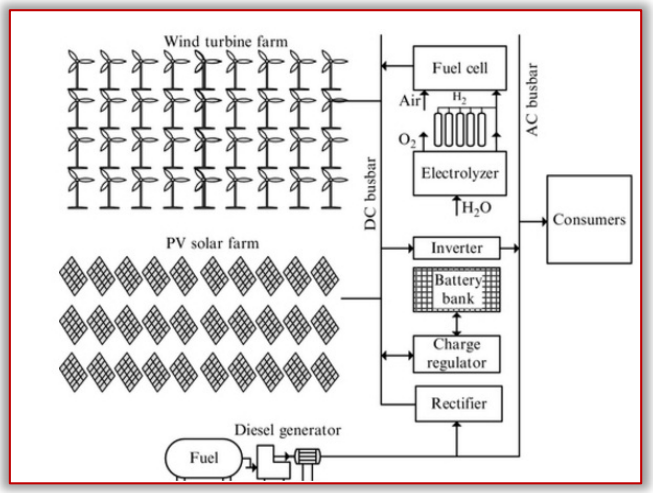

Figure 6. Hybrid Solar-PV, Wind Turbine, and Diesel Power Integrated System

DC TO AC INVERTERS

The conversion circuits that run from a DC voltage source or a DC current source and convert it into an AC voltage or Current are known as inverters. In this case the input to the inverter is a DC source or DC source produced from an AC voltage source. The principle source of input power is possibly utility ac voltage source that is transitioned to DC by an AC-DC rectifier with capacitor filter and then converted into ac supply using an inverter [4].

The dc-ac converter, also known as the inverter, converts dc power to ac power at required output voltage and frequency. We can use existing power supply network or form a rotating alternator through a rectifier or a battery, fuel cell, photovoltaic array or magneto hydrodynamic generator to provide DC power input to the inverter. We can get the constant DC link voltage by adding a filter capacitor across the input terminals of the inverter hence the inverter can be considered as an adjustable-frequency voltage source. The configuration of ac to dc converter and dc to ac inverter is called a DC-link converter.

— Classification of Inverters

Inverters can be broadly classified into two types, voltage source and current source inverters.

≡ Voltage Source Inverters

A voltage–fed inverter (VFI) or a voltage–source inverter (VSI) is one in which we have a dc source with a very small impedance which is negligible. The input terminals have a constant voltage. In the voltage source inverter the main input supply is voltage. The VSI are used to control the output voltages. Also the shape of the ideal VSI output voltage waveform should be autonomous of the load connected to the inverter. DC to AC inverter generates an AC output waveform from a DC source. The VSI are used in various applications such as adjustable speed drives (ASD), uninterruptible power supplies (UPS), active filters, Flexible AC transmission systems (FACTS), voltage compensators, and photovoltaic generators.

Voltage source inverters are applied in three phase or single phase applications. The half-wave and full wave Single-phase VSIs are widely used for power supplies, single-phase UPSs, and intricate high-power topologies when used in multilevel arrangements. Whereas for the sinusoidal voltage waveforms, such as adjustable speed drives (ASDs), uninterruptible power supplies (UPS), and some types of Flexible AC transmission systems (FACTS) devices such as the STATCOM we use three-phase VSIs. Commonly voltage inverters are used in the applications where arbitrary voltages are required [5]

≡ Current Source Inverters

In current source inverters (CSI) the input is changeable current from the dc source of high impedance that is from a constant dc source so in the current source inverter the supply to the inverter is the current source. In case of the current source inverter we control the current output. We use CSI with transistor or thyristor switches. The polarity of input current does not change and the direction of flow of power is determined by the input voltage. The AC (alternating current) wave form with fixed magnitude is produced for a given input. An inductor is connected at the input side of CSIs to maintain the current [6]. The CSIs are used in many applications such as a very high power and high voltage AC motor drives. CSIs can be also applied in motion control systems.

SINGLE PHASE INVERTERS

The voltage source inverters (VSI) are classified on the basis of their construction and their output voltage and their level of implementation. There are three main types of the VSI on the basis of their output voltage as [5]:

1) Single-phase half-bridge inverter
2) Single-phase full-bridge inverter
3) Three phase voltage source inverter

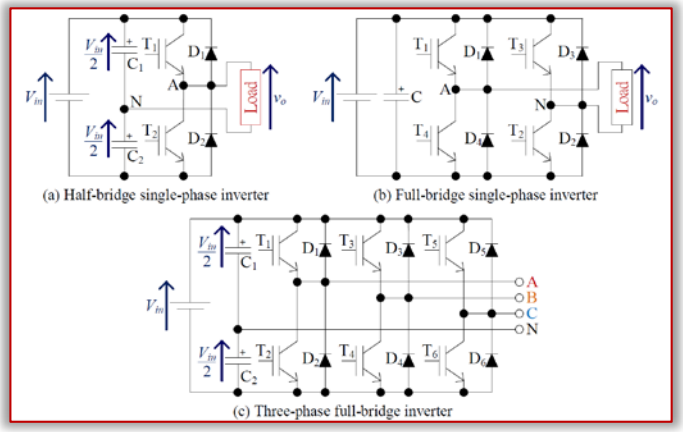

Figure 7. Circuit diagrams for power inverters

— Single phase half bridge inverter

For low power applications we use a Single-phase half-bridge. Fig.7 (a) shows the circuit diagram of a single-phase half-bridge inverter. This inverter consists of two switching devices, T1 and T2 and two diodes, D1 and D2. In this case, IGBTs (insulated gate bipolar transistors) are the switching devices. These two IGBTs and these two diodes build a one-leg or called a half-bridge. D1 and D2 are called anti-parallel diodes of T1 and T2, respectively. If the switching devices are MOSFETs, these diodes are built internally. The input capacitors, C1 and C2, share the input equally. Their voltage is the same and equal to Vin/2. The node between these two

capacitors is the neutral point of the output of the inverter, N, and the node between two IGBTs is the live point of the output of the inverter, A. The T1 and T2 are switched ON and OFF alternatively in order operate this inverter. The duty of the gate signal of each IGBT in the ideal case is 0.5 which is the dead-time between each switching is applied to avoid short circuit in practice. The single phase half bridge inverter can be with purely resistive load and with resistive and inductive load. The idealized wave forms are shown below:

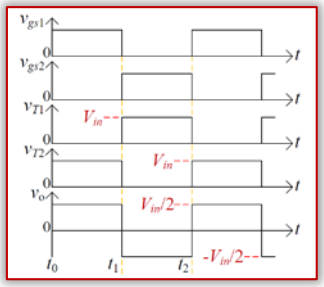

Figure 8. Idealized waveforms of a single-phase half bridge inverter with a purely resistive load

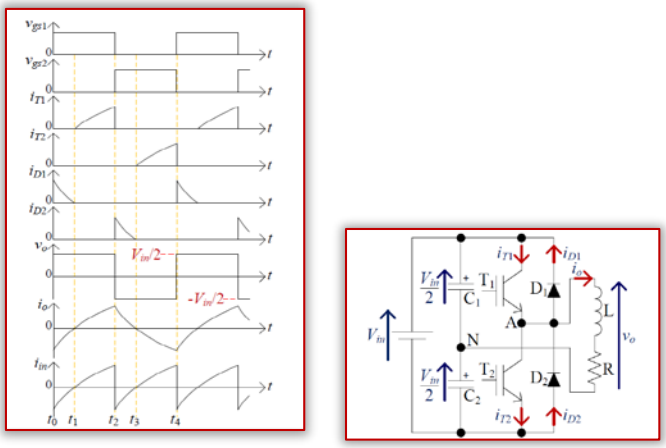

Figure 9. (a) Idealized waveforms of a single phased half bridge inverter with a resistive and inductive load (b) Circuit Diagram of a single-phase half bridge inverter with a resistive and inductive load

— **Single phase full bridge inverter**

When the connect parallel three single-phase half-bridge inverters operating with 120 degrees phase difference we make a single phase full bridge inverter.

As a result, there are 3 legs built with six switching devices and six anti-parallel diodes. This type of inverter is able to produce three-phase line voltages and phase voltages to the load. This converter is commonly operated with 180º and 120º conduction; i.e., 50% duty ratio and 33.33% duty ratio of the gate signals, respectively.

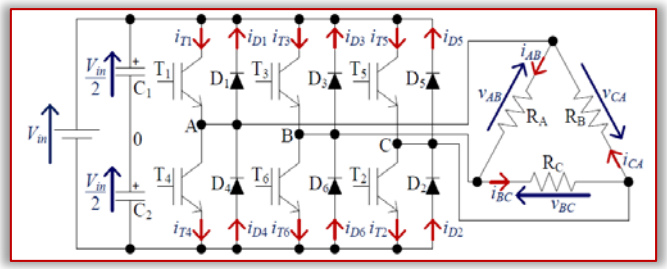

Figure 10. Circuit diagram of a three-phase full-bridge converter

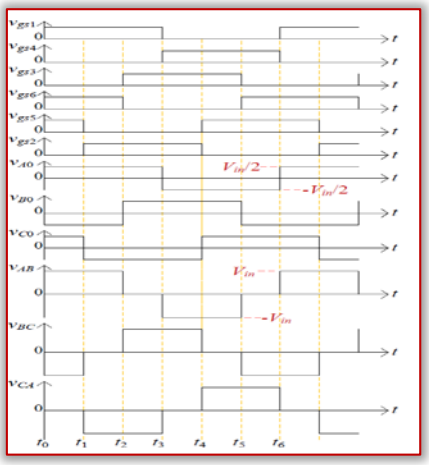

Figure 11. Idealized waveforms of a three-phase full-bridge inverter with a delta-connected resistive load for 180º conduction

The duty ratio of the gate signals of each switching devices are 50%. All the three resistors, RA, RB, and RC, are having the same resistance, R. The peak output line voltage of each phase of the inverter is Vin although the peak values of vA0, vB0, and vC0 are Vin/2. The on-state sequence is T1 & T2, T2 & T3, T3 & T4, T4 & T5, T5& T6, T6 & T1 so that each leg is like a single-phase half-bridge inverter operating with 120 degrees phase difference.

INVERTERS AS MAIN COMPONENTS OF GRID CONNECTED PV SYSTEMS

The components of grid connected systems include the PV array which converts the solar energy into DC power and an inverter which converts the DC power to AC power. The produced power can then be either used up by the load or transferred back to the utility grid. Hence array of solar panels and the inverters are considered as the building blocks of the grid connected system and their study and design is important for installation of any kind of grid connected system.

The performance of grid connected system is highly dependent upon the type of inverter used in solar power design. The inverter converts the dc current into ac for the use by the end user and the access current not required at the load flows back to the grid. When the current starts flowing from PV source to the grid the electric meter starts moving in backward direction and the phenomenon is known as "Net Metering".

The "Islanding" is a state in which part of the utility system taking care of both the loads and the distributed resources remains energized even after being cut off from the main utility.

Hence it is the major need according to the standards that grid connected inverters of solar power systems should always seize transfer of power into the grid under exact abnormal operating conditions of the grid including those leading to the islanding [7].

It is necessary for a solar power grid connected system to have inverters with an anti-islanding protection so that in case the grid fails it shuts down immediately. Also in case of fluctuations in frequency or voltage of grid power inverter must stop working. This helps the equipment to be safe from

potentially damaging events from the grid or the solar grid ties system site. It is highly recommended to use an inverter with fault condition reset which turns the inverter on when grid is operating properly again or can sense and adjust voltages/frequencies appropriately. Latest grid connected inverters are available with all above features along with the internal battery backup, LCD display and maximum power point tracking (MPPT) software examine in real time the voltages and amperes.

The input values of voltages and currents have been increased along with the introduction of automatic morning wake-up and shut down in grid tied inverters. The automatic morning wake-up and shut down functions permits inverter to sleep, reducing its power requirements when there is least or no demand of power [8]

The major task of the inverter includes the control of the output voltage or current of the PV array to produce maximum power at a certain irradiance and temperature. This is called maximum power point tracking (MPPT). The grid tied systems using MPPT inverters are more stable and efficient. The grid tied inverter also controls the sinusoidal current that is transferred into the grid to have the same frequency as that of the grid and a phase shift with the voltage value between the acceptable limits is allowed at the point of connection. Currently, the research is going on to control the quality of injected power and the power factor at the grid interface [7].

The extra functions of grid tied inverter are to take into account voltage amplification in order to be matched with the voltage produced by the PV array and the grid voltage which reduces power losses.

— **Inverter connection topologies of grid-connected PV system**

Photovoltaic systems have various topologies based on the way PV modules are connected with power conditioning unit (PCU). Some of frequently used topologies are [9]

≡ **Centralized topology**

In centralized topology, the centralized inverter is controlling the outputs from a huge number of different solar arrays connected to it. The high power photovoltaic systems where production is in MW can use this topology.

In such connections the cost is minimized and also the maintenance of system becomes easier. The disadvantage is the reliability, which is very low in this case as when a single inverter fails it shuts down the whole solar power system. As only one inverter is used therefore there is considerable power loss of mismatch between the modules and due to shading as tracking is done using MPPT. In effort to minimize these disadvantages and improve the reliability and performance of centralized topology a number of parallel inverters are connected to array so in case one inverter fails the other inverters can still operate and deliver power and prevents system to be shut down. This type of arrangement is called "Master –Slave" topology.

≡ **String topology**

In string topology, single inverters are being connected to individual strings of modules separately. Therefore the combined output from number of strings is not controlled by just a single centralized inverter only. This helps to minimize the losses and increase the reliability of overall system as each string independently operate at its own maximum power point and thus overcoming the drop in power due to the shading issues.

By this kind of typology the mismatch losses are also reduced and there is always a room to add up more modules in a system and thus increasing its size any time according to the requirement. The power rating of each string can be up to 2-3KW. As we use more inverters in this topology so the cost is also increased.

When string topology is combined with master slave concept we call such a combination as "team concept topology".

≡ **Multi string topology**

This type of topology uses advantages of both previously discussed topologies to provide maximum power output. Multiple strings are connected together with their own dc-dc converters and then to a common dc-ac inverter. We can use dc-dc converters for maximum power point tracking which results in voltage amplification. The major disadvantage of using dc-dc converter is that it reduces the reliability and performance.

≡ **Modular topology**

The modular topology is also famous as AC modules. In AC modules an inverter is embedded in each module and one large PV-Cell is connected to dc-ac inverter. The main requirement for grid connection is to have an inverter that can amplify very low voltages 0.5-1.0V and 100W per square meter up to the grid level along with acquiring higher efficiencies. The modular inverter or micro inverter topologies are used for intelligent PV system interface as shown in figure 12.

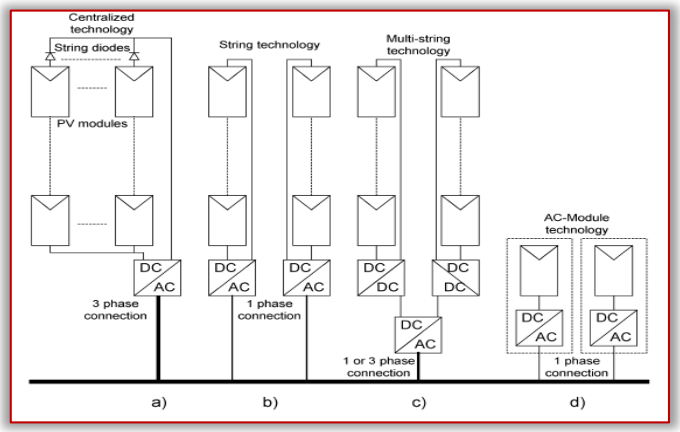

Figure 12. Connection Topologies
a) Centralized Topology b) String Topology c) Multi-String Topology d) AC-Module

— **Categorization of grid connected inverters**

The inverters whether single or three phased are categorized depending on the following basis:

≡ **Number of processing stages**

There are usually three kinds of stages in terms of processing. In the single stage all parameters such as maximum power point tracking, control of grid current, and voltage

amplification all are handled by the inverter itself. In dual stage inverters we use additional DC/DC converter for MPPT. Pulse width modulation (PWM) is used to control the grid current and in third case, each module is independently connected to its own DC/DC converter and all are joined together to the same inverter which controls the grid current.

≡ **Use of decoupling capacitors**

In order to keep the capacitor as small as possible, electrolytic capacitor can be replaced by thin film capacitor. In case of three phase inverter the capacitor must be 10 times smaller [9].The capacitor determines the life of the inverter and it can be placed in parallel with the PV modules or in the DC link between the inverter stages.

≡ **Isolation between AC side and DC side**

It is very important to isolate the DC side of solar power system with the AC side of the Grid and that requirement is fulfilled by using isolated transformer installed at the output side of inverter. As transformer of a commercial frequency is required therefore that can increase the overall weight of the inverter. In order to reduce the weight of inverter, high frequency AC circuit is provided for inverter between the direct current and the commercial AC system. The transformer is then used at high frequency part of the circuit and to achieve the isolation between AC and DC sides.

Transformer less inverters can also be used and in that case no isolating transformer is required instead a circuit for detecting the DC component at AC circuit and ground detection circuit in DC circuit is required.

According to [10] a utility connected inverter which has a very high performance current control scheme can be used effectively in order to improve the power quality in grid connected distribution systems when there is a lot of instability.

— **Inverters to synchronize Grid Tied systems with the utility**

The gird connected inverters are used to integrate the photovoltaic power system with the main utility Grid by using the topologies and the codes for Grid Integration. The standard of power provided by the photovoltaic system for the on-site AC loads and for the power delivered to the utility is judged and governed by practices and quality standards on voltage, flicker, frequency, harmonics and power factor as per recommended by ANSI/IEEE Std 519-1981.

As these inverters are useful because they can convert ac to dc and dc to ac so this characteristic also changes the sinusoidal nature of the ac power current (and consequently the ac voltage drop), resulting in the flow of harmonic currents in the ac power system that can cause interference with communication circuits and other equipments. Therefore when reactive power compensation is used with converters, resonance conditions can cause high harmonic voltages and currents when they occur at a harmonic associated with the converter [11]. Hence it is very important to have minimum harmonics and same sinusoidal waveforms in the dc side of the inverters connected with the solar power system and the ac grid side connected with the utility.

In this paper we are discussing the use of inverters in solar power system as a power device.

THE PULSE WIDTH MODULATION INVERTERS

As discussed earlier the sinusoidal waveform at the inverter side should match the waveform at the output side therefore the voltage to frequency ratio at the inverter output terminals must be kept constant. This avoids saturation in the magnetic circuit of the device fed by the inverter.

The various methods for the control of output voltage of inverters can be classified as:

(a) External control of ac output voltage
(b) External control of dc input voltage
(c)Internal control of the inverter.

In the above mentioned methods the first two methods require the use of some external components however the third method requires no external components and we can use the pulse width modulation for the internal control of the inverter.

— **Principles of PWM**

The pulse width modulation signals are pulse trains with static frequency and scale but with variable pulse width. There is one pulse of fixed magnitude in every PWM period. According to the same modulation signal the width of pulses changes depending on the requirements. When PWM is applied to the gate of transistor. The change in PWM period results in ON and OFF states of the transistors. It is to be noted that the frequency of a PWM signal must be much higher than that of the modulating signal, the fundamental frequency. The energy supplied to the load is mostly depend on the modulating signal.

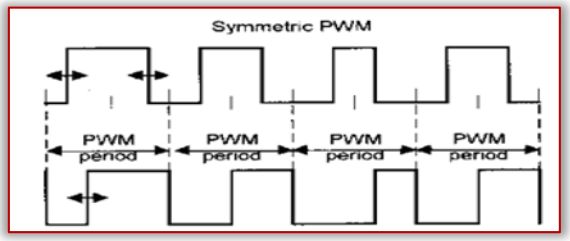

Figure 13. Symmetric and Asymmetric PWM Signals

There are basically two types of PWM signals, symmetric and asymmetric. The pulses of a symmetric PWM signal are always symmetric with respect to the center of each PWM period. The pulses of an asymmetric PWM signal always have the same side associated with one end of each PWM period. Mostly symmetric PWM signals are considered as they result in less harmonics in the output voltages and currents.

— **PWM techniques**

The most common method of controlling the output voltage from the inverter is termed as Pulse-Width Modulation (PWM) Control. The benefits possessed by PWM techniques include lower power dissipation, easy to implement and control, no temperature variation and aging-caused drifting or degradation in linearity, Also the output voltage control can be obtained without any additional components and with this method, lower order harmonics

can be eliminated or minimized along with its output voltage control. The main drawback of this method is that silicon controlled rectifiers (SCRs) most commonly known as thyristors are expensive as they must possess low turn-on and turn-off times. PWM techniques are characterized by constant amplitude pulses. The width of these pulses is however modulated to obtain output voltage control and to reduce its harmonic content. The modulation techniques can be classified into two types mainly carrier based modulation and carrier less modulation. The main purpose of designing these techniques is to control the PWM inverter switches so we can get the AC voltage or current very close to the sine wave form. We can say that by switching ON and OFF the dc supply at regular intervals is considered as the basic method to convert a fixed DC voltage to an AC voltage that is in pure sine wave form. We use PWM in order to achieve this. The quality of these, PWM techniques, depends on the amplitude of the fundamental component, the harmonic content in the inverter output, the effect of harmonics on the source, the switching losses, controllability and implementation.

According to [12] and [13], the main basic idea of the PWM technique is to compare a carrier signal usually a triangular signal with frequency fs with the a reference signal which is a low frequency signal known as modulating signal with frequency fm. The frequency of the reference-modulating signal fm is set the desired output frequency. In Sinusoidal Pulse width modulation technique for getting the pulses, it is required to compare sine wave with triangular wave and in similar way Trapezoidal modulation is a technique to advance the control ability by using computation of PWM patterns. The output frequency of the converter is decided with the frequency of the modulating wave. Space vector PWM (SVPWM) is a digital modulating technique because its control strategies are implemented in digital systems. The purpose of this technique is to produce PWM load line voltages which are in average equal to given (or reference) load line voltages. Inverter with PWM is three stage separate push pull driver, which produces phase waveform independently. SVPWM inverter is used to offer 15% increase in the utilization of dc-link voltage and output which have low harmonic distortions in comparison to conventional sinusoidal PWM inverter. In SVPWM inverter is considered as single unit; specifically, the inverter can be driven to eight unique stages.

In order to get pure sine wave AC output voltage the multi-level PWM technique was developed and is classified as 1) 3-level PWM 2) 5-Level PWM 3) 7 level PWM 4) 9 level PWM and so on. The comparison of different PWM techniques is in following table 1.

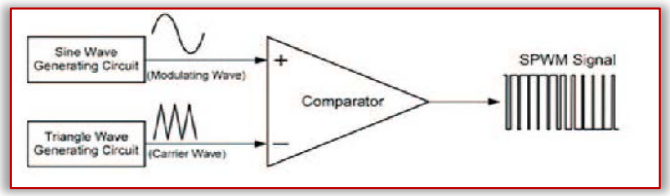

Figure 14. PWM using comparator

Table 1. Comparison of different PWM techniques

No.	PWM Techniques	THD	Complexity	Efficiency
1.	PWM	High	Simple	Low
2.	SPWM	Moderate	Simple	Moderate
3.	SVPWM	Low	Complex	High
4.	Phase Disposition PWM	Moderate	Moderate	Low
5.	Simple Boost Control	Low	Complex	High
6.	Phase shifted PWM	Low	Complex	Very High

PWM CONVERTER IN SIMULINK

The below figure shows how the PWM controller is used to generate the high voltage PWM wave form.

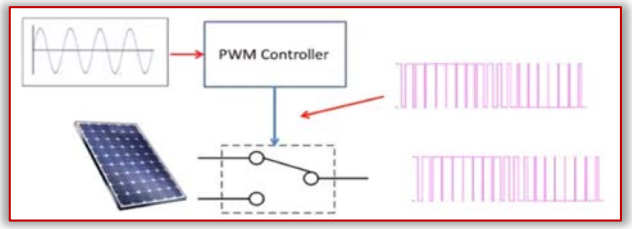

Figure 15. Generation of High Voltage PWM waveform in Solar Power System

The sine wave enters the PWM controller and a square wave signal form is generated. This signal waveform then by using the input signal waveform from the solar power panel is converted to high voltage PWM waveform using a single pole double throw (SPDT) switch. All we can vary is the time of the Switch resulting in Pulse Width Modulation.

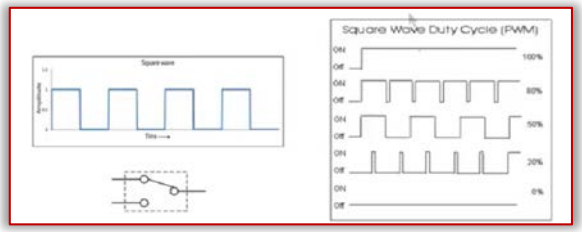

Figure 16. Square wave duty cycle and waveforms

The PWM square wave form obtained above is then passed through the LC filter in order to filter out the harmonics and generate a sine wave. It is seen that average value of the PWM is propositional to the sine wave.

The following figure shows the PWM converter in Simulink Matlab:

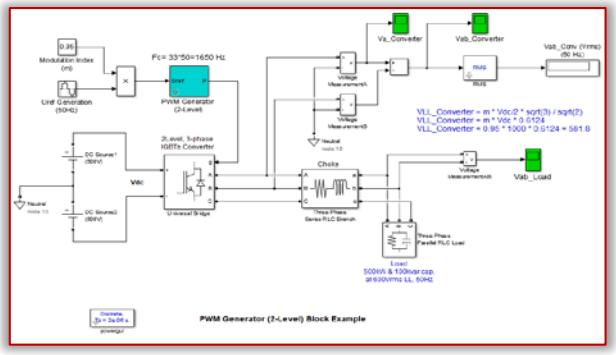

Figure 17. PWM converter in Simulink Matlab

The basic principle as discussed above is that we need a sine wave which is a reference signal at fundamental frequency(which is the frequency required at the output) and then we have a carrier wave which is at higher frequency (usually a sawtooth wave) and then reference is compared with Carrier wave. When Reference wave is greater than carrier wave, output will be high and when reference wave is less than the carrier wave the output will be low. The modulation of pulse is show below:

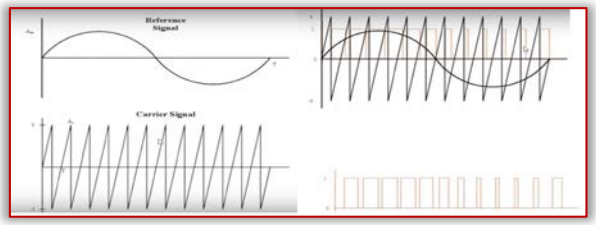

Figure 18. Generation of PWM

When we run the PWM inverter in simulink we get the following outputs for the Inverter.

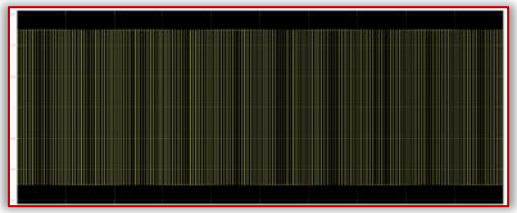

Figure 19. inverter output

Figure 20. Inverter output after passing through Filter

The above outputs show that when modulated signal from the inverter is passed through the RLC filter, we get pure sine wave at the load side of the inverter.

Also in [14], the simulations in Matlab are done to check experimentally the power quality of an off-grid inverter and power quality of the utility network in the UK are discussed and it is observed that the power quality of off-grid system is better than that of the utility network.

CONCLUSION

In this article the inverters as integrators of the solar power system with the utility grids are discussed beside their use as DC to AC converters for the use in Off-grid solar power applications. In detail overview on PWM techniques and the inverters is also provided. The simulation has been done using PWM Generator (2 level block) in Matlab in order to see the output signal waveform at the inverter's output side with and without RLC filter. It can be seen that the output is pure sine wave (AC) after passing through RLC filer.

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OPTIMIZATION OF PAULOWNIA MICROPROPAGATION AT THE LATE CYCLES OF ASEPTIC CUTTING IN VITRO

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Abstract: Paulownia is an important energy and decorative wood crop, which is still new and uncommon in Ukraine. Microclonal propagation of Paulownia elongata × P. fortune at late cycles of aseptic cutting in vitro is accompanied by a decrease in axillary buds activity as well as slow growth and development of cuttings on medium MS with 30 g / l sucrose, 2.5 g / l lysine, 7 g / l agar, and 2.0 mg / l 6-benzylaminopurine. Optimization of the phytohormonal composition of the given medium by adding 1.5 mg / l 6-benzylaminopurine, 1.0 mg / l of gibberellic acid GA_3, 0.5 mg / g adenine and 0.1 mg / l 3-indolylacetic acid allowed to increase the efficiency of in vitro micropropagation of paulownia in late cycles (from the sixth to the tenth) up to the level of early cycles of aseptic cutting.
Keywords: microclones, phytohormones, shoots, activation of axillary buds, nutrient medium

INTRODUCTION

Paulownia is an ornamental fast-growing woody plant (*Zhao et al., 2017; Yang et al., 2019*), which in 5-6 years can reach a height of 20 meters (*Pozoga et al., 2019; Linnik, 2020*). This property of *Paulownia* ensures the popularity of its utilization as a source of renewable energetic materials as well as a rapid restorer of forests, for land reclamation. It is possible to receive 240-350 m^3 of qualitative wood from 1 hectare for 7 years, while the bioethanol yield from 1 ton of dry wood can reach 0,5 t (*Linnik, 2020*). Moreover Paulownia is used in medicine due to antioxidant, anti-inflammatory, cytotoxic, enzyme-inhibitory properties of its flavonoids for both humans (*Cheng et al., 2019*) and animals (*Yang et al., 2019*). *Paulownia* leaves have been used as an admixture to the traditional diet of some farm animals (*Al-Sagheer et al., 2019*). *Paulownia* is also a honey plant with honey productivity of 700 liters per 1 ha (*Linnik, 2020*). For Ukraine, *Paulownia* is a new, uncommon plant that is gaining popularity.

Microclonal propagation of *Paulownia in vitro* provides a rapid rate of creation of pest-, disease-free genetically identical plants (*Rave et al., 2019*). Introduction into *in vitro* culture of nodular explants, petioles and shoot tips can often be used as explants (*Yadav et al., 2013*). The effectiveness of *Paulownia in vitro* cultivation depends on phytohormonal composition of a nutrient medium, in particular on the ratio of auxins and cytokinins (*Shtereva et al., 2014; Pozoga et al., 2019*) 6-benzylaminopurine (BAP), thidiazuron, 3-indolylacetic acid (IAA), kinetin are often used for successful micropropagation of Paulownia (*Yadav et al., 2013*). A positive effect of thidiazuron (0.5-1 mg/l) under the background of IAA (0.1 mg/l) on the frequency of shoot formation and shoot length for six genotypes of *Paulownia* was ascertained (*Shtereva et al., 2014*). The most effective concentration of BAP for regeneration via organogenesis from nodular explants of *P. tomentosa* × *P. fortunei* was 0.5 mg/l (*Pozoga et al., 2019*).

The best results on the proliferation and length of shoots from apical and axillary buds of *P. elongata x P. fortunei* were obtained with1.5 mg/l BAP and 0.1 mg/l indolylbutyric acid (*Rave et al., 2019*).

Most studies on *Paulownia* regeneration efficiency were conducted at the first cycles of microclonal cutting *in vitro* (*Shtereva et al., 2014; Pozoga et al., 2019*), although for prolonged industrial cultivation the production of clones not only at the early cycles of cutting, but also at the later ones seemed to be more rational. The aim of the work was to optimize the technology of *Paulownia* microclonal propagation at the late cycles of aseptic cutting *in vitro*.

MATERIALS AND METHODS

The hybrid *Paulownia elongata* S.Y.Hu ×*P. fortunei* (Seem.) Hemsl. was used as the material. Cuttings, 1 cm long, obtained from annual donor plants were used as explants. For their obnaining young unlignified 2-3-month-old branches were selected for explant obtaining. Explants included a stem section, a node with remnants of two opposite leaves and two axillary buds located in the leaf axils.

Explants were sterilized for 10 minutes in calcium hypochlorite solution and washed five times with sterile distilled water. For shoot formation by activation of axillary buds aseptic explants were put on the hormoneless nutrient medium: macro-, microsalts of MS medium (*Murashige and Skoog, 1962*), 2.5 mg/l lysine, 30 g/l sucrose, 7 g/l agar. Explants were cultured at a temperature of 25 °C, 16-hour photoperiod and light intensity of approximately 1500 lux for 30 days to induce the formation of new formed shoots (NFSs) from axillary buds.

NFSs were aseptically cut off into cuttings which were explanted on the fresh nutrient medium of the same composition and cultivated for 30 days (cycle I of aseptic cutting). NFSs from cycle II of cutting were used to obtain cuttings for the next cycle to continue multiplication. The process of aseptic cutting and the cultivation of NFSs were

continued until cycle X. Cutting cycles I-III were considered as early while cycles IV-X were examined as late cycles of cutting. The effect of growth regulators on the development of *P. elongata* × *P. fortune* at the late (VI) cycle of aseptic cutting *in vitro* was studied for prolongation of multiplication. Growth regulators were added according to the scheme (table 1) to the nutrient medium for cutting with macro-, microsalts MS, 30 g/l sucrose, 2.5 mg/l lysine, 7 g/l agar.

Table 1. The scheme of the investigation of the influence of growth regulators on the development of P. elongata × P. fortune cuttings at the late (VI) cycle of multiplication in vitro

Number of nutrient medium	Growth regulators, mg/l					
	BAP	GA3	Adenine	IAA	Kinetin	2iP
1	1.5	1.0	1.5	0.1	–	–
2	1.5	1.0	0.5	0.1	–	–
3	2.0	1.0	0.1	0.3	–	–
4	2.5	1.0	2.5	0.1	–	–
5	2.5	4.0	2.5	0.5	0.05	–
6	2.5	4.0	2.5	0.5	0.05	0.5

Note. Here and in tables 3-4 (Figure 2-3) the basic medium for cutting contained macro-, microsalts MS, 30 g/l sucrose, 2.5 mg/l lysine, 7 g/l agar; GA_3 – gibberellic acid 3, 2iP – 2-isopentenyladenine.

Forty cuttings were used for each variant of the experiment. The data are reported as x±SE (SE – standart error).

RESULTS

In our experiments on the medium MS with 30 g/l sucrose, 2.5 mg/l lysine, 7 g/l agar and 2 mg/l BAP the depression of axillary buds activity and the slowdown of the growth and development of *P. elongata* × *P. fortune* cuttings in late cycles of multiplication were observed. Then, the number of internodes per 1 explanted cutting at the late (V) cycle decreased 2.6 times and the shoot length – 2.3 times compared to the early (III) cycle (table 2). *P. elongata* × *P. fortune* cuttings at the 2nd and 5th cycles of aseptic cutting are shown in figure 1.

Table 2. Efficiency of *P. elongata* × *P. fortunei* micropropagation at early and late cycles of cutting *in vitro*

Indicator	Aseptic cycle of cutting	
	early (III)	late (V)
The number of internodes of newly formed shoots per 1 explanted cutting, pcs	6.9±0.4	2.7±0.4
The shoot length, cm	3.4±0.4	1.5±0.3

Note. Cultivation on medium MS with 30 g/l sucrose, 2.5 mg/l lysine, 7 g/l agar and 2 mg/l BAP.

At the late (VI) cutting cycle the addition of adenine (0.5 mg/l) gave the possibility to activate almost all *P. elongata* × *P. fortunei* buds with the formation of new shoots (table 3, Figure 2). Increasing the concentration of adenine up to 1.5 mg/l led to the depression of buds activity: only 1.4 buds per cutting were activated with shoot formation. A similar trend was observed in the formation of internodes on newly formed shoots. The number of internodes decreased 1.6 times (from 3.6 pcs. to 2.3 pcs. per shoot) when the concentration of adenine was increased from 0.5 mg/l to 1.5 mg/l. The enlargement of the BAP and adenine concentrations both to 2.5 mg/l did not have a significant effect on the formation of new shoots and their internodes.

Figure 1 – New formed shoots of P. elongata × P. fortune at early (II, left) and late (V, right) cutting cycles in vitro on medium with 2 m/l BAP

Table 3. Influence of growth regulators on the proliferation of shoots via axillary buds activation at the late (VI) cycle of *P. elongata* × *P. fortune* cutting *in vitro*

Number of nutrient medium	The content of growth regulators in the medium for cutting	Number of newly formed shoots per 1 explanted cutting, pcs.	Number of internodes per 1 newly formed shoot, pcs.
1	1.5 mg/l BAP+1.0 mg/l GA_3+1.5 mg/l adenine+0.1 mg/l IAA	1.4±0.4	2.3±0.4
2	1.5 mg/l BAP+1.0 mg/l GA_3+0.5 mg/l adenine+0.1 mg/l IAA	1.9±0.2	3.6±0.2
3	2.0 mg/l BAP+1.0 mg/l GA_3+0.1 mg/l adenine+0.3 mg/l IAA	1.6±0.2	2.9±0.3
4	2.5 mg/l BAP+1.0 mg/l GA_3+2.5 mg/l adenine+0.1 mg/l IAA	1.9±0.2	3.1±0.2
5	2.5 mg/l BAP+4.0 mg/l GA_3+2.5 mg/l adenine+0.5 mg/l IAA+0.05 mg/l kinetin	1.8±0.2	3.4±0.4
6	2.5 mg/l BAP+4.0 mg/l GA_3+2.5 mg/l adenine+0.5 mg/l IAA+0.05 mg/l kinetin+0.5 mg/l 2iP	1.9±0.5	3.1±0.2

Note. Numbers of nutrient media in table 3-4 correspond to the same numbers in table 1.

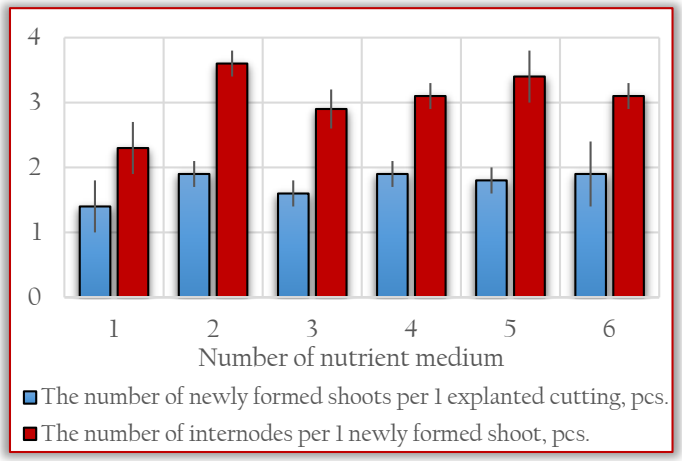

Figure 2 – The development of *P. elongata* × *P. fortune* shoots at the late (VI) cycle of cutting *in vitro* on media with different phytohormones (indicated in table 1)

The tendency to rise the values simultaneously with the complication of medium composition at the cycle VI was established (table 4, Figure 3). At the cycle VI the best result was obtained by reducing the content of BAP from 2.0 to 1.5 mg/l and supplementing the medium with 1.0 mg/l GA_3, 0.5 mg/l adenine, and 0.1 mg/l IAA. On this medium the shoot length increased on average to 3.7 cm, and the number of internodes per 1 explant reached 6.8 pcs. This result is similar to the result obtained at the 3rd cycle of cutting, where the shoot length was 3.4 cm, and the number of internodes of newly formed shoots per 1 explanted cutting was 6.9 pcs.

Table 4. Influence of growth regulators on the growth of P. elongata × P. fortune at the late (VI) cycle of cutting in vitro

Number of nutrient medium	The content of growth regulators in the medium for cutting	The length of newly formed shoots, cm	Number of internodes of newly formed shoots per 1 explanted cutting, pcs.
1	1.5 mg/l BAP+1.0 mg/l GA_3+1.5 mg/l adenine+0.1 mg/l IAA	2,5±0,3	3,3±0,3
2	1.5 mg/l BAP+1.0 mg/l GA_3+0.5 mg/l adenine+0.1 mg/l IAA	3,7±0,4	6,8±0,2
3	2.0 mg/l BAP+1.0 mg/l GA_3+0.1 mg/l adenine+0.3 mg/l IAA	2,0±0,3	4,7±0,5
4	2.5 mg/l BAP+1.0 mg/l GA_3+2.5 mg/l adenine+0.1 mg/l IAA	2,4±0,2	5,9±0,3
5	2.5 mg/l BAP+4.0 mg/l GA_3+2.5 mg/l adenine+0.5 mg/l IAA+0.05 mg/l kinetin	2,9±0,1	6,2±0,3
6	2.5 mg/l BAP+4.0 mg/l GA_3+2.5 mg/l adenine+0.5 mg/l IAA+0.05 mg/l kinetin+0.5 mg/l 2iP	3,3±0,4	5,9±0,5

The worst results at the cutting cycle VI were obtained by increasing the concentration of adenine up to 1.5 mg/l. In this way the number of internodes per explant was almost twice less than at 0.5 mg/l of adenine. The shoot length was the lowest on medium with 2.0 mg/l BAP, 1.0 mg/l GA_3, 0.1 mg/l adenine, and 0.3 mg/l IAA. *P. elongata* × *P. fortune* multiplication at the late (VI) cycle of aseptic cutting on media of studied compositions is shown also in figure 4.

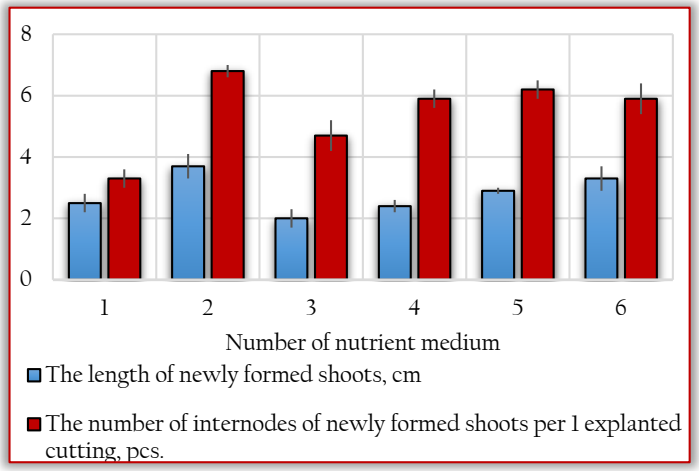

Figure 3 – The extension of *P. elongata* × *P. fortune* at the late (VI) cycle cutting *in vitro* on media with different phytohormones (indicated in table 1)

Thus, the results in tables 3-4 indicate the possibility of effective cultivation of *P. elongata* × *P. fortune* at the late cycles of aseptic cutting under increasing action of growth regulators. The medium MS with 30 g/l sucrose, 2.5 mg/l lysine, 7 g/l agar supplemented with 1.5 mg/l BAP, 1.0 mg/l GA_3, 0.5 mg/l adenine and 0.1 mg/l IAA was the most effective for the late (VI) cycle of cutting.

Figure 4 – P. elongata × P. fortune shoots multiplication at the late (VI) cycle of aseptic cutting, numbers of nutrient media from left to right: 5, 4, 3, 2, 6, 1 (see table 1)

Figure 5 – The exhaustion of P. elongata × P. fortunei after the cutting cycle X in vitro

In our experiments *P. elongata* × *P. fortune* in isolated culture was effectively microcloned up to the cycle X. It became possible due to the mentioned above optimized medium for late cycles of cutting. After cutting cycle X *in vitro* culture of *P. elongata* × *P. fortunei* began to wear out and die (Figure 5).

CONCLUSIONS

The depression of the axillary buds activity of *Paulownia. elongata* × *P. fortune* and slowing down the growth and development of shoots from them was proved to the late (V) cycle of cutting *in vitro* on nutrient medium MS with 30 g/l sucrose, 2.5 mg/l lysine, 7 g/l agar supplemented with 2.0 mg/l BAP. The optimization of the given nutrient medium with 1.5 mg/l BAP, 1.0 mg/l GA_3, 0.5 mg/l adenine and 0.1 mg/l IAA permitted to perform microclonal propagation of *P. elongata* × *P. fortune* in late (VI) cutting cycle on the level of early (III) one. On the given optimized nutrient medium multiplication of *P. elongata* × *P. fortune in vitro* was effective up to the tenth cycle of cutting.

Note:
This paper is based on the paper presented at ISB–INMA TEH' 2020 International Symposium (Agricultural and Mechanical Engineering), 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, 30 October, 2020.

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ALTERNATE FEEDSTOCKS IN THE REFINERY

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Abstract: Over the past four decades, the energy industry has experienced significant changes in resource availability, petro-politics, and technological advancements dictated by the changing quality of refinery feedstock. However, the dependence to fossil fuels as primary energy source has remained unchanged. Advancements made in exploration, production, and refining technologies allow utilization of resources that might have been considered unsuitable in the middle decades of the 20th Century. As the 21st Century opened, the refining industry entered a significant transition period and the continued reassessment by various governments, and the various levels of government, of oil importing policies and oil exporting policies. Therefore, it is not surprising that refinery operations have evolved to include a range of next-generation processes as the demand for transportation fuels and fuel oil has shown a steady growth. A major challenge is the feedstock composition because of the high content of heteroatoms (sulfur, nitrogen, oxygen) and heavy metals (particularly nickel and vanadium) and the high propensity for coke formation which is accompanied by a decrease in the yield of distillates. In addition, the evolution of refinery processing to the use of alternate (non-fossil fuel) feedstocks is also presented in anticipation of domestic and industrial waste into the refinery for blending into conventional (fossil fuel) feedstocks or for separate processing. Many refineries may have already begun such planning by incorporating a gasifier on the refinery site. This will lead to the production of gaseous products, especially synthesis gas – a mixture of carbon monoxide and hydrogen – that can, through the Fisher-Tropsch process, give rise to a variety of products. By understanding the evolutionary changes that have occurred to date, coupled with a presentation of possible future scenarios, this presentation will satisfy the needs of engineers and scientists at all levels from academia to the refinery and help in understanding the refining and prepare for the new changes and evolution of the industry.
Keywords: Refinery configuration, biorefinery, gasification refinery, Fischer-Tropsch synthesis, alternate feedstocks, reconfigured refinery

INTRODUCTION

To meet the challenges from the changing tends in current feedstocks into a refinery to changes in the feedstock composition and also to changes in the product slate, the refinery will adapt to produce the ultimate amounts liquid fuels from the feedstock and maintain emissions within environmental compliance [1, 2, 3]. A major trend in the refining industry market demand for refined products will be in synthesizing fuels from simple basic reactants (such as synthesis gas) when it becomes uneconomical to produce super clean transportation fuels through conventional refining processes. Fischer-Tropsch plants together with IGCC systems will be integrated with or even into refineries, which will offer the advantage of high quality products [4]. This paper presents suggestions and opinions of the means by which refinery processes will evolve during the next three-to-five decades. Material relevant to (i) comparisons of current conventional feedstocks with viscous feedstocks and bio-feedstocks, (ii) the evolution of refineries since the 1950s, (iii) the properties and refinability of viscous feedstocks and bio-feedstocks, (iv) the choice between thermal processes and hydroprocesses, and (v) the evolution of products to match the environmental market.

REFINERY CONFIGURATION

Refineries need to be constantly adapted and upgraded to remain viable and responsive to ever changing patterns of crude supply and product market demands. As a result, refineries have been introducing increasingly complex and expensive processes to gain higher yields of lower boiling products from the higher boiling fractions and residua [5, 6]. Finally, the yields and quality of refined crude oil products produced by any given oil refinery depends on the mixture of crude oil used as feedstock and the configuration of the refinery facilities. Light/sweet crude oil is generally more expensive and has inherent great yields of higher value low boiling products such naphtha, gasoline, jet fuel, kerosene, and diesel fuel. Viscous sour (high sulfur) feedstocks are generally less expensive and produces greater yields of lower value higher boiling products that must be converted into lower boiling products.

— Crude Oil Refinery

A crude oil refinery is an industrial processing plant that is collection of integrated process units (Figure 1). The crude oil feedstock is typically a blend of two or more crude oils, often with viscous feedstocks blended in compatible amounts. With the depletion of known crude oil reserves, refining companies are having to seek crude oil in places other than the usual sources of supply.

The definition of refinery feedstocks is often confusing and variable and has been made even confusing by the introduction of other terms that add little, if anything to crude oil definitions and terminology [3, 5, 6]. The configuration of refineries may vary from refinery to refinery. Some refineries may be more oriented toward the production of gasoline (large reforming and/or catalytic cracking) whereas the configuration of other refineries may be more

oriented towards the production of middle distillates such as jet fuel, and gas oil.

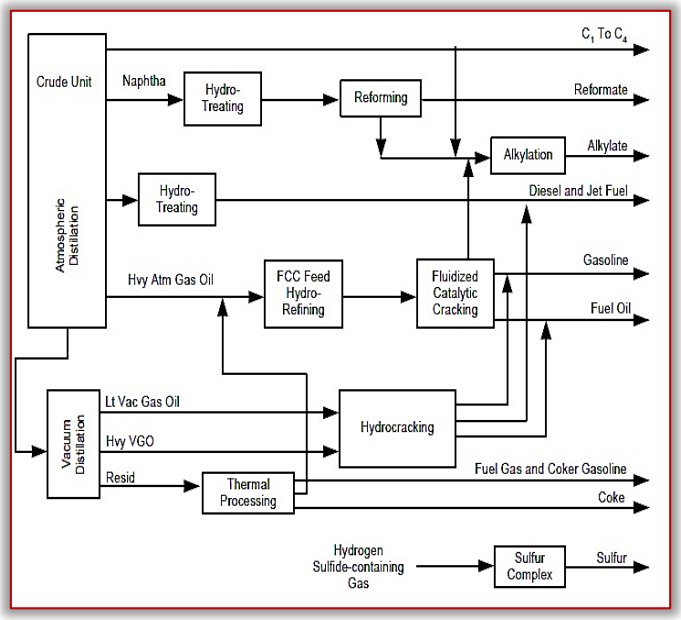

Figure 1. General Layout of a Modern Refinery

Changes in the characteristics of conventional crude oil can be exogenously specified and will trigger changes in refinery configurations and corresponding investments. The future crude slate is expected to consist of larger fractions of both heavier, sourer crudes and extra-light inputs, such as natural gas liquids (NGLs). There will also be a shift towards bitumen, such as the Venezuelan extra heavy crude oil and the bitumen from the Canadian tar sands. These changes will require investment in upgrading, either at field level to process difficult-to-transport heavy crude oil, extra heavy crude oil, tar sand bitumen, either at a field site or at a remote refinery [3, 5, 6, 7].

— Biorefinery

A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass. The biorefinery concept is analogous to the crude oil refinery, which produce multiple fuels and products from crude oil [5, 6]. In fact, there is a renewed interest in the utilization of plant based matter (biomass) as a raw material feedstock for the chemicals industry [8, 9, 10, 11].

Plants offer a unique and diverse feedstock for chemicals. Plant biomass can be gasified to produce synthesis gas; a basic chemical feedstock and also a source of hydrogen for a future hydrogen economy [12]. In addition, the specific components of plants such as carbohydrates, vegetable oils, plant fiber and complex organic molecules known as primary and secondary metabolites can be utilized to produce a range of valuable monomers, chemical intermediates, pharmaceuticals and materials. More generally, biomass feedstocks are recognized by the specific plant content of the feedstock or the manner in which the feedstock is produced [3].

The simplest, cheapest and most common method of obtaining energy from biomass is direct combustion. In fact, the combustion process results in some form of organic residue after their primary use has been fulfilled. These organic residues can be used for energy production through direct combustion or biochemical conversion.

In a manner similar to the crude oil refinery, a biorefinery would integrate a variety of conversion processes to produce multiple product streams such as motor fuels and other chemicals from biomass. In short, a biorefinery would combine the essential technologies to transform biological raw materials into a range of industrially useful intermediates. However, the type of biorefinery would have to be differentiated by the character of the feedstock. For example, the *crop biorefinery* would use raw materials such as cereals or maize and the *lignocellulose biorefinery* would use raw material with high cellulose content, such as straw, wood, and paper waste.

However a word of caution about biomass. The aficionados of biomass use cite the fact that biomass is a carbon-zero feedstock insofar as the carbon dioxide emitted to the atmosphere form the use of biomass is offset by the uptake of carbon dioxide during the growth cycle of the biomass. But there are other, often unmentioned issues that must be addressed.

Biomass also contains varying quantities of metals, including alkali metals, alkaline earth metals, and heavy metals. The alkali metals consist of the chemical elements lithium (li), sodium (Na), potassium (K), rubidium (Rb), cesium (Cs), and francium (Fr). Together with hydrogen they make up Group I of the Periodic Table. On the other hand, the alkaline earth metals are the six chemical elements in Group 2 of the Periodic Table and are beryllium (be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), and radium (Ra). Finally, the heavy metals are less easy to define but are generally recognized as metals with relatively high density, atomic weight, or atomic number. The common transition metals such as copper (Cu), lead (Pb) and zinc (Zn) are often classed as heavy metals but the criteria used for the definition and whether metalloids (types of chemical elements which have properties in between, or that are a mixture of, those of metals and nonmetals) are included, vary depending on the context. These metals are often found in functional molecules such as the porphyrin molecules which include chlorophyll and which contains magnesium. The presence of these metals requires additional treatment to ensure that release into the environment is mitigated.

By analogy with crude oil, every element of the plant feedstock will be utilized including the low value lignin components. However, the different compositional nature of the biomass feedstock, compared to crude oil, will require the application of a wider variety of processing tools in the biorefinery. Processing of the individual components will utilize conventional thermochemical operations and state-of-the-art bioprocessing techniques. The production of biofuels in the biorefinery complex will service existing high volume markets, providing economy-of-scale benefits and large volumes of by-product streams at minimal cost for upgrading to valuable chemicals.

— Gasification Refinery

The most likely option for the integration of alternate feedstock into the refinery is the installation of an on-site gasifier. Thus, such a refinery (often referred to as a gasification refinery) would have, as the center piece, gasification technology as is the case of the Sasol refinery in South Africa [13]. The refinery would produce synthesis gas (from the carbonaceous feedstock) from which liquid fuels would be manufactured using the Fischer-Tropsch synthesis technology [3, 5]. Synthesis gas is used as a source of hydrogen or as an intermediate in producing hydrocarbon derivatives via the Fischer-Tropsch synthesis [12, 14].

In fact, gasification to produce synthesis gas can proceed from any carbonaceous material, including biomass. Inorganic components of the feedstock, such as metals and minerals, are trapped in an inert and environmentally safe form as char, which may have use as a fertilizer. Biomass gasification is therefore one of the most technically and economically convincing energy possibilities for a potentially carbon neutral economy.

Moreover, the gasification of carbonaceous feedstock can provide high purity hydrogen for a variety of uses within the refinery [5, 6]. Hydrogen is used in the refinery to remove sulfur, nitrogen, and other impurities from intermediate to finished product streams and in hydrocracking operations for the conversion of high boiling distillates into low boiling products, such as naphtha, kerosene, and atmospheric gas oil. Hydrocracking and severe hydrotreating require hydrogen which is at least 99% v/v pure, while less severe hydrotreating can use 90% v/v pure hydrogen and above and a current refinery typically requires continuous hydrogen availability [5, 6].

— Fischer-Tropsch Synthesis

The synthesis reaction is dependent of a catalyst, mostly an iron or cobalt catalyst where the reaction takes place. There is either a low or high temperature process (LTFT, HTFT), with temperatures ranging between 200 to 240°C for LTFT and 300 to 350°C for HTFT. The high temperature Fischer Tropsch technology uses a fluidized catalyst at 300 to 330°C (625°F). Originally circulating fluidized bed units were used (Synthol reactors). Since 1989 a commercial scale classical fluidized bed unit has been implemented and improved upon.

The reactors are the multi-tubular fixed bed, the slurry or the fluidized bed (with either fixed or circulating bed) reactor. The fixed bed reactor consists of thousands of small tubes with the catalyst as surface-active agent in the tubes. Water surrounds the tubes and regulates the temperature by settling the pressure of evaporation. The slurry reactor is widely used and consists of fluid and solid elements, where the catalyst has no particular position, but flows around as small pieces of catalyst together with the reaction components. The slurry and fixed bed reactor are used in LTFT. The fluidized bed reactors are diverse, but characterized by the fluid behavior of the catalyst. The low temperature Fischer Tropsch technology has originally been used in tubular fixed bed reactors at 200 to 230°C. This produces a more paraffinic and waxy product spectrum than the high temperature technology.

A new type of reactor (the Sasol slurry phase distillate reactor has been developed and is in commercial operation. This reactor uses a slurry phase system rather than a tubular fixed bed configuration and is currently the favoured technology for the commercial production of synfuels.

PRODUCTS FROM ALTERNATE FEEDSTOCKS

Alternate feedstocks such as the biomass-based feedstocks, can be converted into liquid or gaseous forms for the production of electric power, heat, chemicals, or gaseous and liquid fuels though the varying contents of cellulose, hemicellulose, and lignin (Table 3).

Table 1. Amounts (% w/w) of Cellulose, Hemicellulose and Lignin Common Agricultural Residues and Wastes*

Agricultural residue	Cellulose	Hemicellulose	Lignin
Bamboo	41-49	24-28	24-26
Coastal Bermuda grass	25	35.7	6.4
Corn cobs	45	35	15
Corn stover	35	28	16-21
Cotton seed hairs	80-90	5-20	0
Grasses	25-40	35-50	10-30
Hardwood stem	40-50	24-40	18-25
Leaves	15-20	80-85	0
Newspaper	40-55	25-40	18-30
Nut shells	25-30	25-30	30-40
Paper	85-99	0	0-15
Primary wastewater solids	8-15	NA	24-29
Rice straw	40	18	5.5
Softwood stem	45-50	25-35	25-35
Solid cattle manure	1.6-4.7	1.4-3.3	2.7-5.7
Sorted refuse	50-60	10-20	15-20
Sugar cane bagasse	32-48	19-24	23-32
Sweet sorghum	27	25	11
Swine waste	6.0	28	-
Switch grass	30-51	10-50	5-20
Waste papers from chemical pulps	60-70	10-20	5-10
Wheat straw	33-40	20-25	15-20

*Listed alphabetically rather than by any preferences.

Table 2.

Type	Cellulose	Hemicellulose	Lignin	Others*	Ash
Soft wood	41	24	28	2	0.4
Hard wood	39	35	20	3	0.3
Pine bark	34	16	34	14	2
Straw (wheat)	40	28	17	11	7
Rice husks	30	25	12	18	16
Peat	10	32	44	11	6

*Metals content is not differentiated in this analysis.

The predominant conversion processes are direct liquefaction, indirect liquefaction, physical extraction, thermochemical conversion, biochemical conversion, and electrochemical conversion. More generally, the production

of biofuels from lignocellulosic feedstocks can be achieved through two different processing routes:

- the thermochemical platform and
- the bioconversion platform (Chapter 14).

While each platform is adequate to the task, depending upon the feedstock, there is no clear candidate for best pathway between the various thermochemical technologies and the biochemical technologies.

Table 3. Summary of the Methods for the Conversion of Biomass to Fuels.

Biomass		
Extraction		
	Transesterification	Biodiesel
Hydrolysis		
	Fermentation	Biogas
		Ethanol
Gasification		
	Synthesis gas	Biogas
		Hydrogen
		Methanol
		Ethanol
Pyrolysis		Hydrogen
		Bio-oil
Hydrotreating		Diesel

The thermochemical platform typically uses a combination of pyrolysis, gasification, and catalysis to transform the feedstock into gaseous products – one of which is synthesis gas and then into fuels or chemicals. Synthesis gas) (also referred to as syngas) production through pyrolysis is accompanied by the generation of char, which can then be gasified to provide process heat and energy for the thermochemical platform.

On the other hand, the bioconversion platform typically uses a combination of physical or chemical pretreatment and enzymatic hydrolysis to convert lignocellulose into its component monomers. This platform (examples are anaerobic digestion and fermentation) uses biological agents to carry out a structured deconstruction of lignocellulose components and combines process elements of pretreatment with enzymatic hydrolysis to release carbohydrates and lignin from the wood. The advantage of the bioconversion platform is that it provides a range of intermediate products, including glucose, galactose, mannose, xylose, and arabinose, which can be relatively easily processed into value-added bioproducts. The bioconversion platform also generates a quantity of lignin or lignin components; depending upon the pretreatment, lignin components may be found in the hydrolysate after enzymatic hydrolysis, or in the wash from the pretreatment stage.

Once hydrolyzed, six-carbon sugars can be fermented to ethanol using age-old yeasts and processes. Five-carbon sugars, however, are more difficult to ferment; new yeast strains are being developed that can process these sugars, but issues remain with process efficiency and the length of fermentation. Other types of fermentation, including bacterial fermentation under aerobic and anaerobic conditions, can produce a variety of other products from the sugar stream, including lactic acid. Bioconversion proceeds at lower temperatures and lower reaction rates and can offer high selectivity for products. Ethanol production is a biochemical conversion technology used to produce energy from alternate fuel feedstocks, depending upon the type and properties of the feedstock. For ethanol production, biochemical conversion researchers have focused on a process model of dilute acid hydrolysis of hemicelluloses followed by enzymatic hydrolysis of cellulose. Biodiesel production is a biochemical conversion technology used to produce energy from oilseed crops.

Cellulosic materials can be used to produce ethanol which represents an important, renewable liquid fuel for motor vehicles. Production of ethanol from alternate fuel feedstocks is one way to reduce both the consumption of crude oil and environmental pollution. In order to produce ethanol from cellulosic materials, a pretreatment process is used to reduce the sample size, break down the hemicelluloses to sugars, and open up the structure of the cellulose component. The cellulose portion is hydrolyzed by acids or enzymes into glucose sugar that is fermented to ethanol. The sugar derivatives from the hemicellulose feedstocks are also fermented to ethanol.

The fermentation process requires pretreatment of the feedstock by chemical, physical, or biological means to reduce the complex carbohydrates to simple sugars. This type of pretreatment is often referred to as hydrolysis. The resulting sugars can then be fermented by the yeast and bacteria employed in the process. Furthermore, feedstocks that have a high content of starch and sugar are most easily hydrolyzed. Cellulosic feedstocks, including the major fraction of organics in MSW, are more difficult to hydrolyze, requiring more extensive pretreatment. Fermentation is generally used industrially to convert substrates such as glucose to ethanol for use in beverage, fuel, and chemical applications and to other chemicals (e.g., lactic acid used in producing renewable plastics) and products (e.g., enzymes for detergents). Strictly speaking, fermentation is an enzymatically controlled anaerobic process although the term is sometimes more loosely applied to include aerobic processing as well.

The bioconversion platform is an industrial option that might be used in a biorefinery (Chapter 12) for producing fuels from alternate fuel feedstocks using biochemical reactions and/or biochemical agents. For example, fermentation or anaerobic digestion to produce fuels and chemicals from organic sources is a bioconversion platform. The bioconversion platform therefore has the ability to serve as the basis for wood-based biorefining operations, generating value-added bioproducts as well as fuel and energy for the forest sector.

THE RECONFIGURED REFINERY

Over the past three decades, the refining industry has been challenged by changing feedstocks and product slate. In the near future, the refining industry will become increasingly flexible with improved technologies and improved catalysts. The main technological progress will be directed to:

- upgrading viscous feedstocks,
- production of cleaner – less environmentally threatening – transportation fuel production and
- the integration of refining and petrochemical businesses.

Even the tried and true processes [5, 6] will see changes as they evolve [15].

In the integration of refining and petrochemical businesses, new technologies based on the traditional fluid catalytic cracking process will be of increased interests to refiners because of their potential to meet the increasing demand for light olefins. Meanwhile, hydrocracking, due to its flexibility, will take the central position in the integration of refining and petrochemical businesses in 21st century

The typical refinery in the year 2050 will be located at an existing refinery site since economic and environmental considerations may make it difficult and uneconomical to build a new refinery at another site. Many existing refining process may still be in use but they will be more efficient and more technologically advanced and perhaps even rebuilt (reactors having been replaced on a scheduled or as needed basis) rather than retrofitted. However, energy efficiency will still be a primary concern, as refiners seek to combat the inevitable increasing cost of crude oil and refinery operating expenses.

The refinery of the future will have a gasification section devoted to the conversion of carbonaceous feedstocks, such as biomass, to Fischer-Tropsch hydrocarbon derivatives. The biomass refinery of the future will also use multiple feedstocks but also it will be able to shift output from the production of one chemical to another in response to market demands. Given that biomass will be a part of a refinery of the future, refiners may dictate that biomass receives preliminary upgrading at the biomass site before being shipped to the crude oil refinery.

To circumvent these issues, there may be no way out of energy production than to consorting alternative energy sources with crude oil, and not of opposing them. This leads to the concept of alternative energy systems, which is wider-ranging and more meaningful than alternative energy sources, because it relate to the actual transformation process of the global energy system [16]. Alternative energy systems integrate crude oil with other energy sources and pave the way for new systems where refinery flexibility will be a key target, especially when related to the increased use of renewable energy sources.

Low quality vegetable oils and greases are likely to be promising in a short-to-medium term to yield diesel fuel and jet-fuel by means of hydroprocessing triglyceride-based feedstocks. Also, processing pyrolysis oil requires larger efforts in commercial development because of the overall poor quality of the bio-oils, the conventional hydrotreating catalysts are expected to have a considerably lower catalyst life in bio-oil upgrading operations than that observed with a crude oil-based feedstock. While the current generation commercial catalysts are excellent hydroprocessing catalysts, they are optimized for crude oil-based feedstock and, since the bio-oils have significantly different properties than petroleum feedstock, it would be worthwhile to dedicate efforts to developing catalysts specifically designed for upgrading bio-oils.

Most of the biomass conversion processes carried out in a refinery need a high amount of hydrogen in order to remove oxygen and yield high energy density fuels. Although biomass valorization can be performed on current commercially available petroleum-based technology, it should not be forgotten that crude oil and biomass feedstocks are chemically different. Nevertheless, heterogeneous catalysis, which has made it possible to convert efficiently crude oil-derived resources to fuels, will also be able to provide the necessary technology to get similar fuels starting from biomass feedstocks providing a new catalyst technology is developed [17].

Note:

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METHODS OF CONVERSION OF BIOMASS INTO ELECTRIC AND THERMIC ENERGY

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Abstract: Renewable energy sources such as biomass, solar, hydro and geothermal energy can provide important energy services based on the use of available local resources, studies to date show that the potential of these energy sources is enormous, they can cover in principle several times energy demand. This paper presents some considerations on the methods of converting biomass into convenient energy, respectively the most used method for obtaining biodiesel.
Keywords: biomass, biofuels, bioenergy, solar energy, wind energy

INTRODUCTION

Recent studies on the future development of the energy sector show that in the second half of the 21st century by implementing appropriate strategies, the share of total renewable energy sources can increase from 20% to over 50%, which can help meet current energy needs heating in certain (rural) disadvantaged areas / eg biomass *(I. Sobor et al, 2002)*.

Alternative energy types:

- *Solar energy* - used to produce heat by passive or active conversion methods or to supply electricity through photovoltaic systems. In December 2016, solar photovoltaic energy reached the same price or a lower price than fossil fuel in over 30 countries. Solar energy is the energy emitted by the sun. It is one of the renewable energies. Solar energy is used by humans, animals, plants for various purposes. Plants use solar energy for photosynthesis. The sun's rays are either used directly by man or converted by man into thermal energy (heat) or electricity *(Zhang D.et al, 2015)*.
- *Wind energy* - used to produce electricity with wind turbines; Wind energy, a form of renewable energy, it has been used since the beginning of humanity as a means of propulsion on water for various boats and later as energy for windmills. The countries with the highest installed capacity on wind farms are China, the United States, Germany and Spain. At the beginning of 2011, the share of wind energy in total domestic consumption was 24% in Denmark, 14% in Spain and Portugal, about 10% in Ireland and Germany, 5.3% in the EU. The percentage is 3% in Romania at the beginning of 2012. At the same time in Romania there were over 1000 wind turbines, half of them being in Dobrogea *(A. Cherubini et al, 2015)*.
- *Hydroenergy* - hydroelectric power plants with an installed capacity less than or equal to 10 MW (low hydropower), respectively hydroelectric power plants with an installed capacity greater than 10 MW (high hydropower).
- *Geothermal energy* - energy stored in underground geothermal hydro deposits and deposits, exploitable with special drilling and extraction technologies.
- *Biomass* - comes from residues from forestry and agricultural exploitations, wood processing waste and other products; biogas is the result of anaerobic fermentation of animal manure or from municipal wastewater treatment plants *(M.B. Hagberg et al, 2016)*.

Biomass, for most of history, has been the primary energy source powering human development. This energy supply has taken various forms, including wood and dung for cooking and heating, charcoal for metallurgy, and animal feeds for food and transportation. With increasing concerns regarding human impacts on the environment, humanity is once again looking towards biomass resources to meet a significant portion of our energy needs. The challenges today in using biomass are many, but can best be related to scale and density. The scale of energy needed far exceeds all past demands; both the increasing world population and the energy intensity of modern life compound the need for energy as never before. Similarly, the distances over which energy is moved and the concentration of population into dense urban centers results in the need for fuels with high energy density to insure overall efficiency of use. Over the past century, the developed world has enjoyed cheap and abundant energy supplies through the adoption of a fossil energy economy (Nallathambi Gunaseelan V., 1997). The 1900 shave been declared the "Petroleum Century", with both positive and negative connotations. The widespread use of petroleum allowed rapid economic expansion throughout the industrialized world, increasing national and personal affluence, and enabled the modern ideal of personal automobile owner-ship. With expanded automobile ownership came an increasing demand for liquid transportation fuels, a demand that led to a shift in primary production.

Huge demand for various oils and their high prices is an apprehension for the mankind. Since there is an increased

awareness for eco-friendly issue, there is an urgent need to explore the alternative energy sources. Various alternative energy sources like nuclear power, solar, wind and biofuels are well known, where biofuels (solid, liquid, gas fuels) sounds as one of the best representative candidates in terms of usage and the production process. Biofuel, is the process where energy of organic materials (renewable biomass) is replaced the function of fossil fuels. When gasoline supply and demand are inelastic, they serve as a buffer supply of energy, helping to reduce prices (*Weiland P., 2009; Vlăduţ. V. et al., 2016*). The inelasticity of supply and demand is an assumption which is valid in the short run, whereas in long term both supply and demand are elastic . Processes like trans-esterification which converts animal and vegetable oils into usable 2 fuel forms. From different sources, algae, produces a large amount of energy. Algae represent as the significant group of biological systems, where few of them are known to produce vast quantities of lipids relative to their total biomass. However, it is important to note that the technology has so far not been sufficiently developed to allow these biofuels to be produced commercially. Economics is playing a crucial role in ensuring a smooth transition to a biofuel future. Biomass and biofuels are the only renewable energy source that can replace fossil fuels directly for our present and future energy constraints (*Weiland P.,2009; Nallathambi Gunaseelan V.,1997*).

MATERIALS AND METHODS

Biomass represents an abundant carbon-neutral renewable resource for the production of bioenergy and biomaterials, and its enhanced use would address several societal needs.

Advances in genetics, biotechnology, process chemistry, and engineering are leading to a new manufacturing concept for converting renewable biomass to valuable fuels and products, generally referred to as the biorefinery. The integration of agroenergy crops and biorefinery manufacturing technologies offers the potential for the development of sustainable biopower and biomaterials that will lead to a new manufacturing paradigm (*Chiru A. et al, 2010*).

The term biomass applies to the mass of substance generated by the development of living organisms, be they microorganisms, plants or animals. The term also includes agricultural products, waste from agriculture or from the processing of agricultural crops, including cereal straw, residues from the production of sugar, starch, beer, etc. (*Lunguleasa A. et al., 2007*).

Biomass is a form of storage of solar energy in the chemical energy of molecules of organic substances, being one of the most popular and widespread resources on Earth. It provides not only food, but also energy, building materials, paper, fabrics, medicines and chemicals. Biomass has been used for energy purposes since the discovery of fire by man, so that today it is used from heating rooms to producing electricity and fuel for cars (*Ed. J. Coombs and D. O. Hall. London, 1981*).

The ability to produce electricity from biomass is based on its physical and chemical properties. A very important parameter is the humidity, respectively the dry matter content of the biomass.

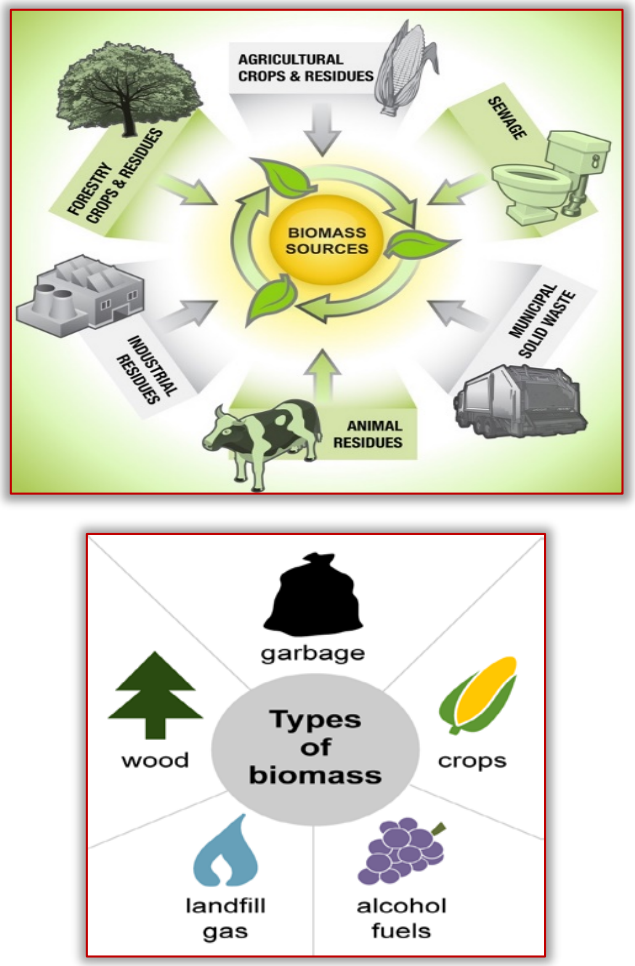

Figure 1. Biomass sources *(Chiru A. et al, 2010)*

Biomass can be converted into convenient energy by several methods. These conversion methods are:

- Thermal conversion of biomass (dry process):
  - Combustion;
  - Pyrolysis;
  - Gasification;
- Biochemical or biological conversion of biomass (wet process):
  - Fermentation;
  - Anaerobic digestion.
- Mechanical conversion of biomass.
- Chemical conversion.

RESULTS

— Thermal conversion of biomass

Combustion: the process of direct combustion of biomass is the most widely used process of energy use. This process is verified in practice and commercially available at very high levels. Combustion devices have different designs and performance, they are able to burn any wood fuel (timber), bales of straw to municipal waste. It is important to burn wood and agricultural waste (straw). The heat generated is used in manufacturing processes (heat processing) and power generation. Wood combustion takes place in the following stages (*Aghamohammadi N. et al, 2011*):

- The water inside the lumber starts to boil (old and relatively dry wood contains 15% water in the cell structure);
- The wood fuel gas is gradually released, for a good combustion it is important that the gas is burned not released through the chimney;
- The resulting gas is mixed with atmospheric air and burned at high temperatures.
- The rest of the wood (mostly carbon) burns well, and produces ash waste.

For efficient combustion it is necessary to ensure:

- Sufficient air;
- Sufficiently high temperature;
- Enough time to ensure complete combustion of biomass.

Although direct combustion is the simplest and most widely used way to use biomass, it is not always an efficient process. The design of a combustion boiler, which is characterized by a much higher efficiency, requires an understanding of the entire combustion process. An important step is to understand the evaporation of water from the lumber, a process that consumes energy. The energy consumed, however, represents only a small part of the available energy. Modern combustion devices are very similar to those used for coal and have a combustion efficiency of 90%.

Pyrolysis consists in the thermochemical decomposition of solid biomass, a process that takes place at temperatures of 300-800°C and in the absence of oxygen. This process results in heat, various gases (hydrogen, methane, carbon monoxide, etc.), bio-oil and coal. Combustible gases can be separated and captured, and the resulting coal, also called biochar, can be used as fertilizer and agricultural amendment, a use that is also an efficient and economical way to sequester carbon.

There are many technological variants of biomass pyrolysis, all of which are characterized by relatively high costs, to which the initial stage of biomass preparation also contributes (storage, drying, crushing and feeding). Heat transfer to solid biomass is also a technological challenge, as a slow transfer favors coking (see Figure 2). Pyrolysis in fluidized bed reactors is the most widespread technological variant for the production of bio-oils, its principle scheme being presented in figure 3. A bed of sand or other thermally stable material at operating temperature is maintained in a "fluid" state, in suspension, by introducing a stream of hot gas at the bottom of the reactor. Subsequently, the reactor is fed with crushed biomass, in a very small proportion, so that the heat transfer takes place almost instantly to the biomass particles.

This principle is the basis of many technologies, the differences between them being to address the problems raised by the formation of coal and coke in the fluidized bed, the accumulation of ash and heat recovery (*Lunguleasa A. et al, 2007*).

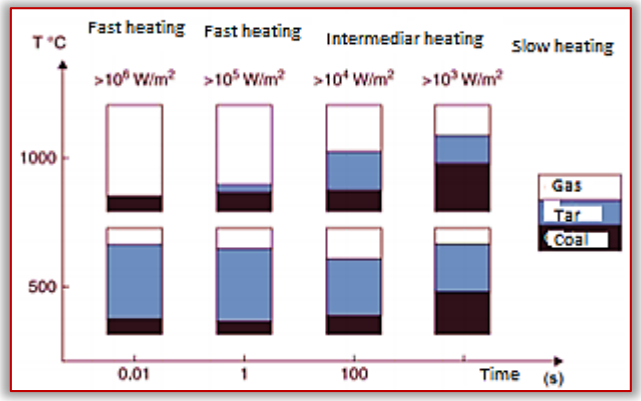

Figure 2. Variation of pyrolysis products with temperature and exposure time

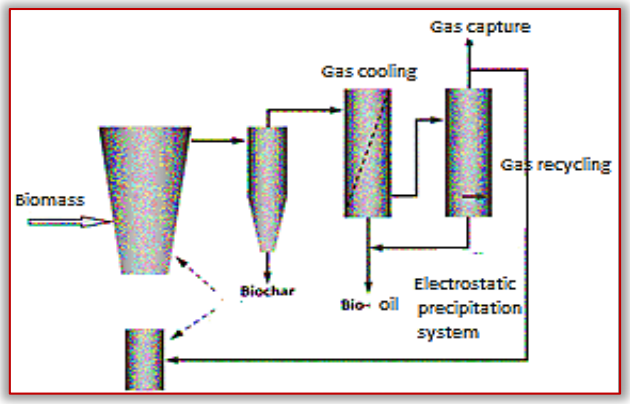

Figure 3. Pyrolysis of biomass in fluidized bed reactor *(Lunguleasa A. et al, 2007)*

Gasification: is a process by which solid fossil fuels, natural gas or biomass are transformed into a combustible gas, called synthesis gas (singaz) or biosingaz, mainly representing a mixture of carbon monoxide and hydrogen, plus carbon dioxide (CO_2) and possibly hydrocarbon molecules, such as methane (CH_4) and is one of the earliest and oldest energy conversion processes. In general, the gasification process is defined by the reaction between the solid fuel with an oxidizing agent (air or oxygen) in the presence of the moderator (steam) at a high temperature between 1200 - 1500ºC and resulting in the synthesis gas used to generate of electricity or as a raw material for the synthesis of substances such as methanol, urea, ammonia, etc. (*Lunguleasa A. et al, 2007*).

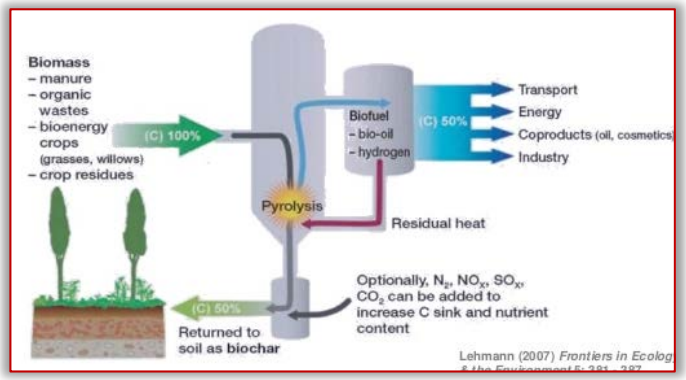

Figure 4. Thermal conversion of biomass *(Nallathambi Gunaseelan V., 1997)*

— Biochemical or biological conversion of biomass

Fermentation: is generally used for the production of bioethanol and includes the following steps: the biomass is crushed, then the starch is converted into sugars by enzymes, followed by sugars being converted into bioethanol by yeast (an organism that secretes catalytic enzymes) and finally separation and purification of bioethanol by distillation. The conversion by fermentation of ligno-cellulosic biomass such as wood and herbaceous plants is a more complex process due to the presence of large molecule polysaccharides and requires acidic or enzymatic hydrolysis before the resulting carbohydrates pass into bioethanol by fermentation.

Fermentation of carbohydrate-rich matter with the help of anaerobic bacteria or green algae can produce hydrogen, especially in the absence of light. The process that uses fermentation in the dark produces H_2 and CO_2 combined with other gases such as CH_4 or H_2S, depending on the biomass used and the process reactions.

Anaerobic digestion: is a microbiological process of decomposition of organic matter, in the absence of oxygen, found in many natural environments and applied today on a large scale for the production of biogas in reactors, sealed against air ingress, generically called digesters. A wide variety of microorganisms are involved in the anaerobic process, resulting in two final products: biogas and digestate.

Digestate is anaerobically decomposed biomass, rich in micro and macro nutrients that can serve as fertilizer for plants (*Mitroi A. and ML-A. Imireanu*).

— Mechanical conversion of biomass

Mechanical conversion is not a proper conversion of biomass, because it does not change the nature of biomass. These conversions consist of mechanical processes of compressing biomass (compaction, pelletizing, briquetting, etc.) in order to use it in thermal processes (*V. Arion et al*).

— Chemical conversion of biomass

Chemical conversion consists in the transformation of mechanically processed biomass and its transformation into vegetable oil, by treatment with an alcohol and generation of esters (eg methyl esters and glycerol). In the next stage, the purified biodiesel can be burned in diesel engines.

Currently, biodiesel is mainly produced in batch reactors. The use of ultrasound in the transesterification of oils into biodiesel allows continuous line processing at any scale. Ultrasonication leads to an increase in biodiesel yield of up to 99%. Ultrasonic reactors reduce the processing time to less than 30 seconds (conventional processing 1 - 4 hours / batch). More importantly, ultrasonication reduces the separation time from 5-10 hours (using conventional agitation) to less than 60 minutes.

The most widely used method for obtaining biodiesel is enzymatic transesterification with methanol (methanolysis). The reaction takes place by heating a mixture of 80-90% oil and 10% and 20% methanol, respectively, plus a small amount of catalyst. The biodiesel resulting from this reaction is called FAME - Fatty Acid Methyl Ester. The following figure shows the general scheme of the process of transesterification of organic oils into biodiesel by methanol (*V. Arion et al*).

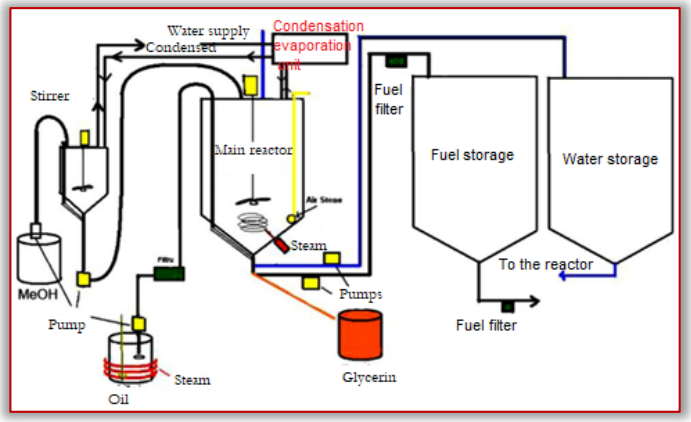

Figure 5. Schematic representation of the technology for the production of methyl esters by transesterification *(https://en.wikipedia.org/wiki/Biomass)*

CONCLUSIONS

Like wind, solar, and other renewable energy sources, biomass can make a positive impact on our atmosphere by lessening our dependence on climate change-inducing fossil fuels. Biomass energy differs from other renewables, however, in the extent to which its use is directly tied to the farms, forests, and other ecosystems from which biomass feedstocks are obtained. Because of this close association, the use of biomass has the potential to result in a wide range of environmental and social impacts, both positive and negative, above and beyond its use as a substitute for fossil fuels. Impacts on soils, water resources, biodiversity, ecosystem function, and local communities will differ depending on what choices are made regarding what types of biomass are used, as well as where and how they are produced. This is why biomass needs to be produced and harvested as sustainably as possible. In this sense, sustainability refers to choosing management practices that minimize adverse impacts and complement local land-management objectives, such as farm preservation, forest stewardship, food production, and wildlife management (*Swithenbank et al, 2011*).

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EFFECT OF MILLING PROCESS AND STORAGE PERIOD ON THE PROXIMATE CHARACTERISTICS OF RICE GRAINS

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Abstract: The effect of milling and storage period on the proximate composition of rice grains where studied. Two rice varieties (MAS and IRR I8) commonly produced in Ebonyi State were used for the study. Results revealed that at first month (freshly milled rice) the moisture contents of MAS rice was 40.40%, while the protein content, fat, ash and carbohydrate content respectively, recorded 6.90%, 0.50%, 0.90% and 79.30%. It recorded a total nutritional content of 98% at first month storage period. As the month progresses, it was observed from the results that the proximate profile of the rice continued to decrease in value. After two months of its storage, the moisture content of the rice dropped to 7.40% while the available protein reduced to 6.60%, the fat, ash and carbohydrate contents dropped to 6.0%, 0.89% and 78.86%, respectively. The reduction in the proximate composition of MAS rice continued until 14 to 18th month of its storage and then maintained constant values of 3.43%, 5.90%, 0.1%, 0.51% and 53.06%, respectively for moisture content, protein, fat, ash and carbohydrate contents. Furthermore, at first month of the storage, the IRRI8 rice recorded the moisture content, protein, crude fat, ash and carbohydrate content of 9.61%, 6.90%, 0.60%, 0.90% and 78%, respectively. It had a total nutritional content of 97%. With time, the proximate status of the IRRI8 rice was observed to depreciate in values. The moisture contents, available protein, crude fat, ash and carbohydrates after two months of storage dropped to 9.50%, 6.70%, 0.59%, 0.87% and 76.43%, respectively. The decrease in the nutritional values maintained constant values of 3.15%, 5.80%, 0.20%, o.47% and 50.39%, respectively for moisture contents, protein, fat, ash and carbohydrate. The variation in the rice proximate composition was attributed to the differences in the variety, milling process and nutritional losses resulting from length of storage period.
Keywords: Rice, proximate composition, milling, storage period

INTRODUCTION

Rice (*oryza Sativa*) is consumed in different forms around the world such as brown rice, milled rice, parboiled milled rice etc. (Zubair et al., 2015). According to IRR (2013) rice is the most important and extensively grown food crop in the world. It is a staple food for nearly half of the world's seven billion people and of all the staple crop, rice has risen to position of incomparability. Since 1970's, rice consumption in Nigeria has risen tremendously at about 10% per annum due to changing consumer preferences. Rice is a food that is very rich in carbohydrate and also an important cereal crop that supplies a quarter of the entire caloric intake of the human race (Cecelia et al., 2004). The nutritional components of rice include the following: Carbohydrates, fat, water, ash, and protein. Rice cultivars are sometimes classified according to the conditions under which they are grown such as upland rice – grown as rain-fed crop where there is adequate rainfall (3-4 months). Swamp rice or lowland rice – grown on flooded land.

The rice grain is comprised of the endosperm and seed coat. Most rice is consumed as white polished grain. A lot of nutrients are lost when bran is removed in milling. It can only be consumed in milled form. The consumer acceptance and preference of rice depend on the quality of the milled rice. Among the many forms which is processing; parboiling of rice is widely used which is the hydrothermal treatment of paddy rice prior to milling. The quality of milled parboiled rice is being assessed based on physical parameter like degree of milling, broken grain, grain size, colour and shape. The amount of impurities (stones) also affects the overall quality of milled rice. Those qualities are not only dependent on the rice varieties, parboiling process and storage changes the physical properties and reduces nutrient loss during milling.

According to (Oko et al., 2012) the milling process produces four fractions in rice: brown rice, hull, white rice and bran. Each of these fractions can vary in chemical content according to the variety of rice and the type of milling performed. They noted that unmilled rice contains a significant amount of dietary fibre and contain more nutrients than milled or polished white rice. Most rice is consumed as white polished grain despite the valuable food content of brown rice. The complete milling and polishing that converts brown rice into white rice destroys 67 % of the vitamin B3, 80 % of the vitamin B1, 90 % of the vitamin B6, half of the manganese, half of the phosphorus, 60 % of the iron, and all of the dietary fibre and essential fatty acids (Ensminger and Ensminger, 1986). These nutrients are lost when bran is removed during milling.

Rice grains are bagged and stored in warehouse at ambient conditions, which ranges from 29^0 – 33^{0}C and 65 – 75% relative humidity (Donahaya et al., 2004). It is the conventional storage system where most cereals are exposed to ambient air. Thus, paddy and its main products are

susceptible to reduction in its nutrients value and insect attack. Storage of milled rice for a long period reduces its nutrients. Houston, (1972) investigated the influence of temperature, moisture content and milling degree on the development of off-odours during air tight storage of milled rice and observed that high temperature, high moisture content and low milling degree enhance odour deterioration. According to Anonymous (1997) nearly twenty percent of the world's dietary energy is provided by rice alone which is higher than either wheat or maize. The crude fibre reduces the risk of bowel disorders. The high proportion of unsaturated fatty acids such as oleic and linoleic acid present in rice bran lowers blood cholesterol. Whole grains are good source of iron, thiamine, niacin and riboflavin. Bran is rich in micronutrients such as oryzanols, tocopherols, tocotrienols, phytosterols and dietary fibres like betaglucan, pectin and gum which have hypolipidemic, anti-tumor, anti-oxidant, ergogenic and laxative properties (Devi, 2015). However rice consumers often prefer to have polished white rice despite the valuable food content of brown rice which is lost when bran is removed while polishing.

Knowledge about the nutritional values of milled and stored rice is important among consumers in view of nutritional paucity and/or disorder. For health reasons, consumers are conscious of having rice with good cooking quality, eating quality and also nutritional quality (Devi, 2015). Therefore, the objective of this study is to investigate the impact of milling and storage period on the proximate characteristics and/or composition of rice.

MATERIAL AND METHOD

— Research Materials

Two varieties of rice grains (MAS and IRRI8), commonly grown in Ebonyi State (freshly milled) were obtained from Abakaliki rice milling industry and used for the study. The two varieties were grinded to obtain the same particle size of flours for proximate analysis. The varieties were kept in two different bags for the period of study. The rice grains samples were further bagged and stored for a period of eighteen months to assess the changes in their nutritional composition based period of storage.

— Determination of moisture content

Five grams (5g) of each sample was weighed, transferred into an oven and dried at 50°C for 5 hours. Re-weighing at intervals of 30 minutes, thereafter, allowed to cool in a desiccator. Equation 1 according to (Waheed, 2014) as adopted by Agu et al. (2016) was used to obtain the moisture contents of the rice samples

$$M.C = \frac{WS - W0}{W1 - W0} X\ 100\% \quad (1)$$

where, M.C = Moisture content, % (w.b); Weight of empty moisture can = W_0; Weight of can + Sample = W_1; Weight of can + Oven dried sample = W_3

— Determination of crude ash

The crude ash was determined using the following steps adopted by Agu et al. (2016): Crucible was washed, dried in the oven and allowed to cool in the desiccator; 2g of dried material was placed in an empty porcelain crucible which has been previously ignited and weighed; Ignite the material over a low flame or on a hot plate in the fume cupboard to char organic matter; Crucible was placed in a muffle furnace maintained at a temperature of 60°C for six (6) hours; The crucible was transferred directly to a desiccator, cooled and weighed immediately. Then equation 2 was used to evaluate the ash content of the rice samples

$$\text{Percentage ash} = \frac{WcA - Wc}{Ws} \times 100 \quad (2)$$

where, W_{CA} = weight of crucible + Ash (g); W_C = weight of empty crucible (g); W_S = weight of sample (g)

— Determination of crude fat

Fat was determined by washing a 250-300ml extraction flask, allowed to dry in the oven, cooled in a desiccator and weighed according to Feri and Becker (2003).

The following procedure was used to determine the fat content of the rice samples: The soxletextractor was flitted up with reflex condenser and water flow started; 5g of dried sample on a filter paper was folded, and transferred into a fat-free extraction thimble and plugged tightly with a cotton wool; The thimble was placed into the extraction barrel and added petroleum ether/hexane until it siphons over once in the flask directly; Flask and reflux sample was heated for 5 hours; After the extraction the thimble was removed from the extraction barrel and dried; The flask containing the fat was dried in the oven at low temperature. Then the flask plus fat was weighed and calculated using the expression

$$\text{Fat (\%)} = \frac{\text{Weight of dry sample}}{\text{weight of sample}} \times 100 \quad (3)$$

— Determination of protein

The protein content of the rice sample was determined by the routine of semi- micro kjeldal procedure which consists of three (3) techniques of analysis, namely: Digestion, Distillation and Titration. 0.2g sample in a digestion flask was weighed. 0.8g of mixed catalyst powder was added. 10ml of concentrated H_2SO_4 was fixed in the flask into the digester for 3 hours until a clear solution was obtained.

The digest was cooled and transferred into a 100ml volumetric flask and make up to mark with distilled water; 5ml of 4% boric acid was pipette into a conical flask and 2 drops of indicator added; The conical flask and distillation flask was fixed in a place and 7ml of 40% NaOH was added through the glass funnel into the digest. The steam exit was closed and timing started until when the solution of the boric acid and indicator turns blue. (75ml distillate was collected). Distill was done for 15minutes. The distillate was titrated with 0.01 NHCl and calculated thus; (Agu et al., 2016)

$$\text{Nitrogen (\%)} = \frac{14.01 \times \text{sample titre} - \text{blank titre} \times N \times 6.25}{\text{sample weight}} \quad (4)$$

where, N = normality of acid

— Determination of Carbohydrate

Twenty milligrams (20mg) of the rice sample was transferred to 100ml graduated cylinder. 10ml of water was added and stirred, also 13 ml of perchloric acid was added and stirred with glass rod for about 15 minutes, then the

mixture was transferred into a 250ml volumetric flask. The cylinder was washed and stirrer into the flask and make up to 250ml mark and shacked thoroughly. 5mls was filtrated into a test tube and Pipette 1ml of the filtrate into a test tube in duplicate. 1ml of distilled water was pipette in duplicate as a blank. 1ml of glucose standard solution was pipetted.
5mls of freshly prepared anthrone reagent was pipette into all the tubes and mix thoroughly. It was placed in a boiling water bath for exactly 12 minutes and then cools quickly to room temperature. The cuvettes were matched by reading distilled water in both and note the differences in reading for correction in the calculation.
The solution was transferred in turn, to one glass cuvette washing the cuvette in between readings. The percentage carbohydrate was obtained from reading the optical densities of the sample and standards at 630mm against the reagent blanks using the expression

$$\text{Carbohydrate (\%)} = \frac{2.5 \times b}{a \times W} \quad (5)$$

where, w = weight of sample; b = optical density of sample; a = optical density of standard

RESULT AND DISCUSSIONS

Table 1 presents the variation in the nutritional values of milled MAS rice variety stored between the storage periods of 1 – 18 months. Results as recorded in this table revealed that at first month of storage (freshly milled) the moisture contents of MAS rice was 40.40%, while the protein content, fat, ash and carbohydrate content of the rice respectively recorded 6.90%, 0.50%, 0.90% and 79.30%. It recorded a total nutritional content of 98% at first month of storage period.
The drop in the total nutritional composition of the rice from 100% to 98% was attributed to the loss resulting from the effect of milling and polishing process. This is evidence that rice loses nutrients (bran content) which is highly nutritional during the process of milling as observed by Oko et al. (2012). The proximate values obtained at first month storage period of MAS rice fall within the range of proximate values obtained for milled miniket rice by Zubair et al. (2015). As the month progresses, it was observed from the results that the proximate profile of the rice continued to decrease in value. After two months of its storage, the moisture content of the rice dropped to 7.40% while the available protein reduced to 6.60%, the fat ash and carbohydrate contents dropped to 6.0%, 0.89% and 78.86%, respectively.
The reduction in the proximate composition of MAS rice continued until 14 to 18th month of its storage and then maintained constant values of 3.43%, 5.90%, 0.1%, 0.51% and 53.06%, respectively for moisture content, protein, fat, ash and carbohydrate contents. The variation (reduction) in the proximate values showed that milled rice loses its nutritional values during storage periods.

Table 1. Variation in nutritional status of MAS variety between 1 – 18 months of storage period

Period (month)	Water (%)	Protein (%)	Fat (%)	Ash (%)	CHO (%)	Total (%)
1	10.40	6.90	0.50	0.90	79.30	98.00
2	7.40	6.60	0.60	0.89	78.86	94.05
6	6.58	6.20	0.40	0.75	74.07	88.00
10	3.64	5.90	0.20	0.81	70.75	81.00
14	3.43	5.90	0.10	0.51	53.06	63.00
18	3.43	5.90	0.10	0.51	53.06	63.00

Table 2 revealed the variation in the proximate composition of milled IRRI8 rice stored between the periods of 1 – 18 months. At first month of the storage, the IRRI8 rice variety recorded the moisture content protein, crude fat, ash and carbohydrate content of 9.61%, 6.90%, 0.60%, 0.90% and 78%, respectively. It had a total nutritional content of 97%, shorting 3% of its total food content during milling process resulting from the removal of bran (during polishing).
Oko et al. (2012) reported that the nutrients content of rice are lost when bran is removed during milling and that is why health conscious people prefer brown rice to milled rice. Results of the proximate values obtained within the first month of the storage of the milled IRRI8 fall within the values obtained by Devi et al.(2015) for 92 rice genotypes and slightly lower than the values obtained by Zubair et al. (2015) for milled miniket rice. The variation in the rice proximate composition according to Pomeranz (1992) is attributed to the differences in the variety and mostly to processing method used in which milling is paramount.
Furthermore, as storage period progresses, the proximate status of the IRRI8 rice was observed to depreciate in values. The moisture contents, available protein, crude fat, ash and carbohydrates after two months of storage dropped to 9.50%, 6.70%, 0.59%, 0.87% and 76.43%, respectively. The decrease in the nutritional values maintained constant values of 3.15%, 5.80%, 0.20%, o.47% and 50.39%, respectively for moisture contents, protein, fat, ash and carbohydrate. Finally, rice is a good source of insoluble fibre, insoluble fibre reduces the risk of bowel disorders and fights constipation. Dietary fibre is highest in the bran layer and lowest in the milled rice. Unfortunately, this bran layers are being removed during the process of milling (Oko et al., 2012).

Table 2. Variation in nutritional status of IRRI8 variety between 1 – 18 months of storage period

Period (month)	Water (%)	Protein (%)	Fat (%)	Ash (%)	CHO (%)	Total (%)
1	9.61	6.90	0.60	0.90	78.00	97.00
2	9.50	6.70	0.50	0.87	76.43	94.00
6	8.03	6.40	0.30	0.77	65.80	81.00
10	6.60	5.90	0.21	0.48	50.80	71.00
14	3.15	5.80	0.20	0.47	50.39	60.01
18	3.15	5.80	0.20	0.47	50.39	60.01

Figure 1-6 present the effect of storage period on the nutritional composition of milled rice. Figure 1 revealed that MAS rice had the highest moisture content of 10.4% at first month of storage period as compared to IRRI8 with moisture

content of 9.61% at first month of storage period. The curves in this figure steeped downwards from the maximum value of the nutrient (10.4% for MAS and 9.61% for IRRI8) at first month (drop in moisture content) up to 14th - 18th month in which it maintained constant and minimum values of nutritional contents (3.43% for MAS and 3.14% for IRRI8).

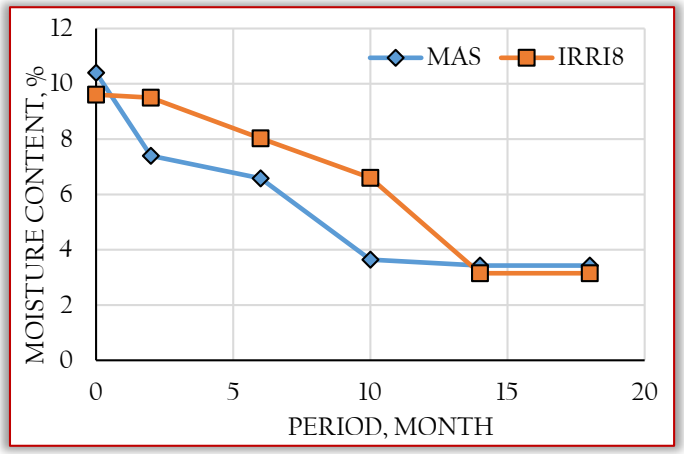

Figure 1. Effect of storage period on moisture content of milled rice

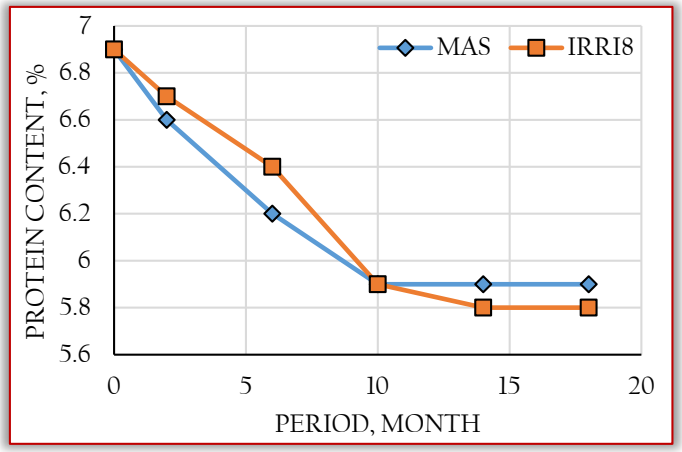

Figure 2. Effect of storage period on period content of milled rice

However, the percentage moisture losses across the varieties were not the same; the moisture content of MAS dropped at faster rate than the IRRI8 within the store periods. This variation was attributed to the differences that exist among different varieties of milled rice as observed by Pomeranz (1992) and Oko et al. (2012).

The curves of protein content of the rice varieties (fig. 2) steeped downward from the maximum value of 6.90% to 5.90% within the storage period of 1 to 18 months for MAS while the curve of IRRI8 followed the same trend, dropping from maximum proximate value of 6.90% in the first month of storage period to 5.80% within 14 – 18 months of the storage period. The variation in the rate at which both varieties lost their available protein content was almost at the same range.

Figure 3 presents the effect of storage period on the crude fat content of the rice varieties. The curves in this figure revealed that the IRRI8 recorded the highest crude fat content of 0.60% at first month and 0.20% within 14 – 18th month while the MAS steeped from 0.50% at first month down to 0.10% within 14 – 18th months of its storage. Both varieties lost about 0.4% of their crude fat at different rates during the storage period.

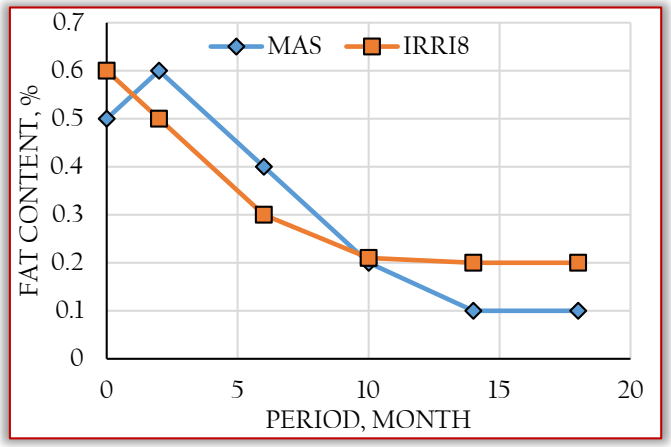

Figure 3. Effect of storage period on fat content of milled rice

Figure 4 presents the effect of storage period on the crude ash composition of MAS and IRRI8 rice varieties. Both curves in the figure steeped downward from 0.90% at first month of storage period where they had the same maximum nutritional ash, to minimum values of 0.50% for MAS and 0.47% for IRRI8 at the storage period of 14 – 18 months. Within the storage period of 18 months, the MAS rice lost total ash content of 0.47% while IRRI8 lost about 0.43% of its ash content.

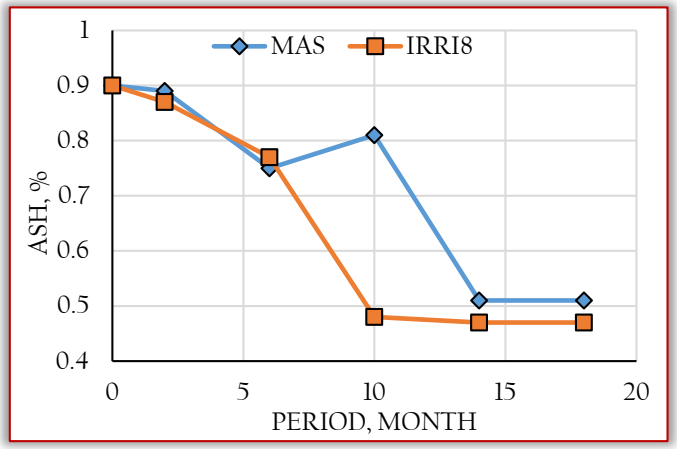

Figure 4. Effect of storage period on ash content of milled rice

Figure 5 revealed the effect of storage period on the carbohydrate composition of the rice varieties. According to this curves, the MAS rice with the highest carbohydrate value of 79.30% at first month of storage period as compared to IRRI8 with carbohydrate content of 78.00% at first month of storage period steeped downward from the maximum value (79.30%) and dropped gradually to a minimum carbohydrate value of 53.06% within the storage period of 14 – 18th month. On the other hand the IRRI8 rice variety steeped downward from its maximum carbohydrate content of 78.00% at first month of storage period to a minimum value of 50.39% within the storage period of 14 -18th month.

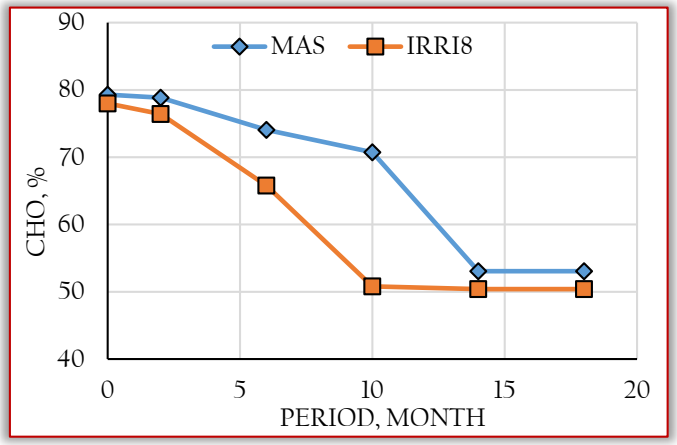

Figure 5. Effect of storage period on carbohydrate content of milled rice

Figure 6 showed the curves of the total food on nutritional content at a given storage period of the rice varieties. The curves steeped downward from the maximum value of food content where the MAS rice with the highest nutritional content of 98% at first month of storage to the minimum nutritional content of 63% within the storage period of 14 – 18th month while the curve of the total food content of IRRI8 rice steeped downward from its maximum value of 97% at first month to minimum value of 60.01% within the storage period of 14 – 18 months. Results of these curves indicated that rice under storage lose their nutritional composition from first month of their storage after milling and/or polishing up to 13th months of the storage period and from the 14th month, the deterioration in the nutritional value maintain constant values. It is therefore not a good practice to store rice for a very long period especially after milling.

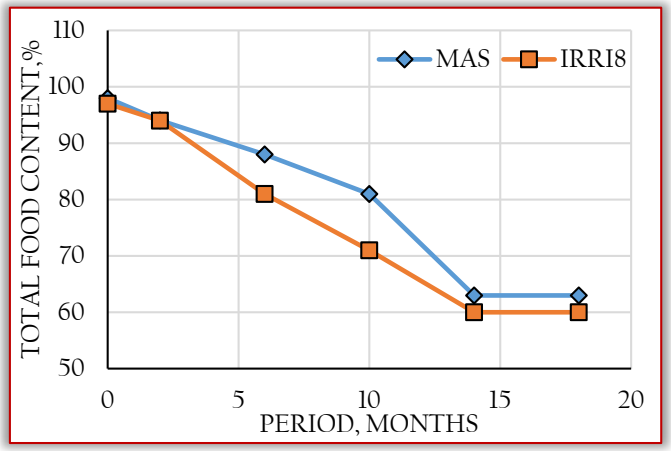

Figure 6. Effect of storage period on the total food content of milled Rice

CONCLUSION

From the findings made, the following conclusions can be made about the study:

— Milled rice has its highest nutritional content at zero month of its storage period. Thereafter, as the storage time progresses, the rice begins to lose its nutritional composition.

— The bran layer of rice grain contains the dietary fibre which is very nutritious and medicinal. This component of rice is removed during the milling and polishing process of rice grains.

— The variation in the proximate composition of rice is attributed to the differences in the varieties, processing method in which milling is paramount and nutritional loss resulting from length of storage period.

— Milled rice under storage gradually loses its nutritional composition from 0 – 13th month of its storage and from 14th month they maintain constant nutritional values till the rest of the period.

It is therefore recommended that rice should not be stored for a very long period after milling to be able to retain its nutritional content. Finally brown rice is preferred to milled and polished rice for consumption because of its bran content which embodied the fibre that is very nutritious and also medicinal in value.

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INCREASING THE PRODUCTIVITY OF THE ELDAN INSTALLATION – CASE STUDY

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Abstract: The recycling of materials is the object of activity of Remat Bucharest; here being processed approx. 150-160 tons of copper cables, 50-ton aluminum cables and 150-200 tons of used tires per month. The ELDAN installation started its operation in the second semester of 2010, demonstrating a greater flexibility than expected, in terms of materials to process. The material introduced on the ELDAN installation goes through the following technological flow: chopping, granulation, electrostatic separation. Electrostatic separation is based on the difference between the conductivity of the materials that make up the mixtures of ground materials from cables: conductive metals and non-conductive plastics. The productivity of the installation has increased considerably due to two improvements: a) the introduction of calcium carbonate ($CaCO_3$) in the technological process of processing car cables. Because the temperature inside the schredder (MPR) is very high (due to friction) the cable sheaths stick together and sometimes even melt, so that their processing becomes impossible; by introducing this dust on the conveyor belt we managed to process approximately 5.5 tons of car cables on an 8-hour work shift; b) proposing and manufacturing of a Ø5 mm sieve, which made it possible to process new types of cables (cords). The standard sieves, offered by the manufacturer of the installation were Ø4, Ø6, Ø8 and Ø10 mm. These improvements are reflected in the increased productivity of the plant.
Keywords: productivity, ELDAN, copper wire, recycling

INTRODUCTION

The widespread use of copper, processed in different forms, leads to the accumulation of significant amounts of waste. Recycling is important not only in terms of reducing the amount of waste, but also due to the reuse of copper products, because the production of copper from recycled products requires 85% less energy than the production of copper ore. Recycled copper has the same characteristics as mining copper [1].

The copper industry is at the forefront of industries committed to reducing the environmental impact of its operations. Today, a third of the energy consumption in the copper manufacturing process in modern Europe is used to take measures to protect the environment [2].

Due to its very high electrical conductivity, the main field of use of copper is the production of metal conductors for the energy industries. It is a durable material that continues to function throughout the life cycle of a product, without significant loss of performance. In general, copper waste from electrical cables is recycled and reintroduced into the production process of electrical wires and cables but can also be used in other applications, such as copper castings [3].

Metallic copper is produced in many countries. Figure 1 shows the continental distribution of primary copper production. About 88% of copper production comes from the processing of copper-containing ores. The remaining 12% is provided by the recycling of copper from waste [4, 5]. Currently, the copper mining industry is relatively small but efficient in Europe, and smelters and refineries (copper producers) are world class. In fact, European companies are the pioneers of many metallurgical processing technologies now used around the world. Europe boasts a prominent semi-finished sector, which turns both copper and waste into a wide range of Cu and Cu alloy products for further use in the value chain [1, 2, 6, 7].

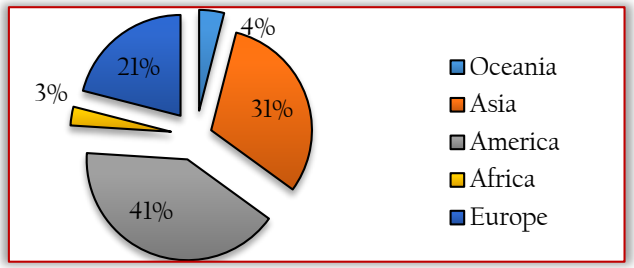

Figure 1. Distribution by continents, of primary copper production

Recycling remains a key element in covering the copper requirement. Copper can be recovered from most of its applications and reintroduced into the production process without losing quality in recycling. With very limited access to primary sources of copper in domestic markets, EU industry has traditionally paid close attention to so-called "surface mines" relying heavily on waste supply to reduce the trade gap in raw materials for Cu [2, 8].

According to some studies, it has been estimated that 95% of the old copper waste that is available is recycled. In 2015, 44% of total copper demand in Europe was secured from recycling. The energy required for recycling represents about 20% of that required for primary production (from mining). Moreover, the relatively high value of copper, combined with easy recyclability, is a key factor in the recovery and recycling of products that have reached the end of their life cycle, which would otherwise be lost [9, 10].

According to statistics, the electronics and electrical engineering industries are the most important in terms of the amount of copper processed, using almost 60% of the total amount of copper processed in the EU (Figure 2) [2, 11-13].

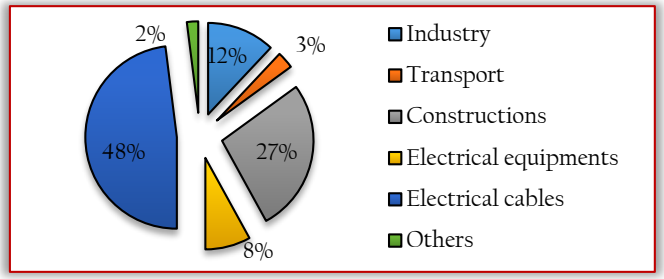

Figure 2. Copper consumption in Europe

In 2010, 2.25 million tons of copper were reused - a 14% increase in one year - from end-of-life products and waste recycled directly to the factory (from direct smelting). This high percentage of copper recycling is determined by the increasing use of metal in European society [2, 4, 13].

Cu and Cu alloys castings accounted for only 5% of castings production in Romania in 2011 [1].

Innovations, close cooperation with customers, plus anticipation of market needs, have become the attributes of success for the semi-finished copper industry in Europe. All this requires investment in product research and development, plus flexible equipment, able to meet the highest quality requirements [14, 15].

The research and testing of new concepts developed by the copper industry, results in a constant flow of innovations that can completely transform the way some equipment is manufactured and how it works. These innovations can make processes cheaper or minimize the impact on the environment, reduce energy consumption or improve design. Whatever they do, they are only due to the superior properties of copper. Innovations based on copper and copper alloys are applied in many other industries and help those in these sectors to design and manufacture new products and applications that will continue to improve our daily lives [16, 17, 18].

MATERIALS AND METHODS: Copper cables

This waste comes from factories specializing in the production of automotive electrical installations and equipment. Today REMAT Bucharest processes approx. 150-160 tons of copper cables, 50 tons of Al cables and 150-200 tons of used tires per month.

In the case of recycling electrical cables, if we recycle cables whose conductors are made of thicker copper wires (Figure 3a), then mechanical separation is sufficient. If flexible cables with many very thinner copper wires are recycled (Figure 3b), or telephone cables or waste from the electronics industry are recycled, mechanical separation is not efficient enough.

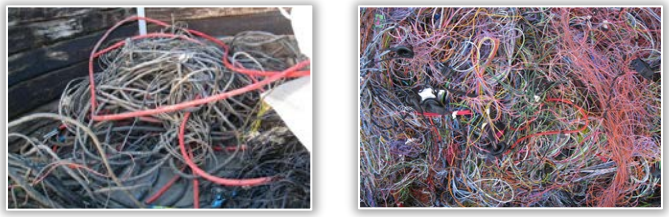

Figure 3. Copper cables

In such a situation electrostatic separation is a particularly efficient solution. Using this method, the various plastics can also be separated (Figure 4).

ELDAN installation

The material introduced on the ELDAN installation goes through the following technological stages: chopping, granulation, and electrostatic separation. The ELDAN installation has shown greater flexibility than expected in terms of materials to process.

The principle of operation consists in loading with electric charges for a certain time the surfaces of non-conductive materials, either by bombardment with ions or electrons, or by friction and thus, the charged particles can be separated from the other uncharged (non-conductive ones). The particles move in a field generated by an electrode of direct current and high voltage (over 35 kV), loaded with electric charges. The conductors will be unloaded immediately and will be removed from the drum under the action of centrifugal force. The non-conductive particles will adhere to the drum, being maintained by their own load, and from here they will be directed to another area by brushing.

Separation occurs because different electrostatically loaded materials give way to the charges with which they are charged at different time intervals. In this way, being forced to cover a certain distance on a rotating metal drum electrically connected to the ground, they detach from the drum at different times.

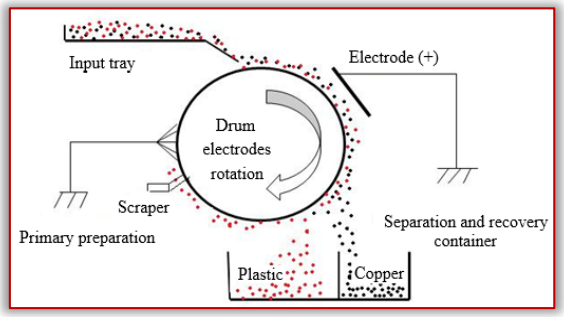

Figure 4. Copper electrostatic separator

The main equipment that is part of the ELDAN installation is the following:

— Dimensional homogenization system of the raw material (Figure 5a and 5b) S1000 rough grinding system composed of input belt; shredder; vibrating trough and conveyor belt; magnetic belt; EC electrostatic separator and conveyor belt.
— MPR 120W system composed of input belt; MPR pregranulator; vibrating trough and conveyor belt; magnetic belt; and filter system.
— HG169 fine grinding system composed of feeding silo; heavy granulator / fine granulator and pneumatic transport system.
— Separation installation composed of feeding silo; separation table; annexes to the separation table (classifier, exhaust belts, pneumatic transport for return); filter system.

The ELDAN Super Chopper is designed to process more volume and hard waste. It chops the material to a size that is

easier to handle. The purpose is to facilitate transport or increase capacity in the recycling plant.

Figure 5. a) Super Chopper, b) Vibrating trough and conveyor belts

Cable / wire waste is loaded using a graft machine directly into the Super Chopper's feed tank. The chopped material is evacuated by means of a vibrating trough and is transported by means of belts in the silo of the MPR pregranulator. The material resulting from the MPR pregranulator has dimensions between 15 and 20 mm, is driven on a vibrating trough where a second magnetic strip separates the remaining ferrous metal fraction and is transported by means of belts in the feed silo of the fine granulator. The granulated material between 4 and 7 mm resulting from the fine granulator is transported through a pneumatic transport system to the silo that feeds the separation mass. On the separation table the non-ferrous metal fraction separates from the non-metallic fraction, and an intermediate fraction is sent by pneumatic transport again to the fine granulator. The non-ferrous metal fraction (Cu for copper cables or Al for aluminum cables) is evacuated by means of a conveyor belt which has at the end an electromagnetic drum for separating the remaining iron and stainless steel, in different containers. The non-metallic fraction (which has a low content of non-ferrous materials) is sent to a classifier where through a sieve system combined with motion / vibration it purifies the non-metallic fraction (plastic) separating it from non-ferrous materials entrained with it to the classifier.

The obtained material was analyzed to determine the constituent elements by means of X-ray fluorescence spectrometer (Portable XRF Thermo Scientific Niton XL3t).

RESULTS AND DISCUSSIONS

The diameters of the copper cables used were within the limits of 10 - 40 mm for thicker cable (Figure 3a) and 2 – 12 mm for the thin ones. These were composed of a set of copper wires covered with an insulating layer of PVC, PP or PE, followed for some types of cables, by a layer of steel and a coarse PVC jacket. This waste comes from factories specialized in the production of DIY electrical installations, from the dismantling of Electrical and Household Waste, the decommissioning of telecommunication networks, etc. (Figure 3).

To improve the productivity of the ELDAN installation and to be able to process the cables, we have brought the following improvements:

— For the first batch we proposed and manufactured an Ø5 sieve (Figure 6), which made it possible to process some types of cables (cords).The standard sieves offered by the manufacturer of the installation were Ø4, Ø6, Ø8 and Ø10.Due to this, we were able to process an additional 152,398 tons, which represents an increase of 8.34% compared to the usual production.

Figure 6. Manufactured Ø5 sieve

— For the second batch we introduced calcium carbonate ($CaCO_3$) in the technological process of cables processing. Since the temperature inside the chopper is very high (due to friction) the cables become sticky, sometimes they even melt, so their processing is impossible. Therefore, by introducing this powder on the conveyor belt, we are currently able to process approximately 5.5 tons of cables in an 8-hour work shift. In 2020, due to this improvement, the ELDAN section processed in addition to the usual production 85.973 tons, which represented an increase of 4.71%. For the first batch, were obtained the following quantities of recovered materials after processing 7.047 tons of copper cables:

— Copper granulates: 3.939 tons (56.32%) - (Figure 7a).
— Steel waste: 0.300 tons (4.26%).
— Plastic (grinded insulation): 1.958 tons (18.30%).
— Classifier 2 (fine Cu10%+Plastic 90%): 0.183 tons (2.60%).
— Losses (dust + fine plastic): 0.050 tons (0.75%).

Figura 7. Result after processing: a) Batch 1; b) Batch 2

For the second batch, were obtained the following quantities of recovered materials after processing 10.893 tons of copper cables:

— Copper granulates (stranded wire): 7.843 tons (72.56%) - (Figure 7b).
— Steel waste (including lower stainless steel): 0.012 tons (0.14%).
— Plastic (grinded insulation): 1.958 tons (18.30%).
— Classifier 2 (Cu stranded wire 7% + Plastic 93%): 0.487 tons (4.56%).
— Losses (dust + fine plastic): 0.593 tons (4.84%).

The constituent elements by means of X-ray fluorescence spectrometer (Thermo Scientific Niton XL3t) were presented in Table 1.

Table 1. Chemical compositions of the recovered material

No. crt.	Symbol	CC1	CC2	CC3	ACC
1	Al	0.618			0.206
2	P	0.036	0.058	0.075	0.056333
3	Fe	0.059	0.050	0.160	0.089667
4	Cu	99.15	99.00	99.24	99.13
5	Sn	0.064	0.353	0.095	0.170667
6	Ni		0.426	0.106	0.177333
7	Cr			0.066	0.022
8	Zn			0.176	0.058667
9	Pb			0.069	0.023
Total		99.927	99.887	99.987	99.93367

In conclusion, through the contribution to the ELDAN section, we managed to produce an increase of 13.05% compared to the normal production capacity before these changes.

In April 2021, 121.41 tons of copper cables were purchased and processed. The processing resulted in 79.63 tons of copper granules (54.78%). The total purchase price was 294,327 Euros. Following the sale of the copper granule, 546,953 Euros were obtained. The total processing cost for April was 26,710 Euros.

CONCLUSIONS

By using ELDAN installation for recycling copper cables were obtained superior results, the reduction of processing costs, low energy consumption and maintenance costs. The metal losses were minimal, and the purity of the metal was 99.5%.

The metal is mechanically processed by chopping and electrostatically separated with the addition of calcium carbonate to limit the adhesion to the cutting knives and on the conveyor belts of the non-metallic sticky parts. In addition, by adding Ø5 mm sieve, a significant amount of metallic material could be recovered.

At the same time, the ELDAN plant demonstrates greater flexibility than expected in terms of materials to process. Today, the system can also successfully process used tires.

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USING THE LASER SCANNING FOR CONSERVATION OF CULTURAL HERITAGE BUILDINGS

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Abstract: This work is part of the INTEREG IPA CBC Romania Serbia project entitled RORS394 Know to Develop – Through knowledge to business and smart development of Banat. The project's objective was to increase employment opportunities and employability of young people through the creation of organizational and institutional conditions for cross-border and networked improvement of education, knowledge and skills that will meet the needs of the economy and labour market. One of the modules of the project refers to 3D scanning as a high-resolution and accurate recording of the objects in 3D space is of high importance for many subjects of different domains of interest such as monitoring landslides, archaeology, cultural heritage etc. Traditional techniques for 3D data acquisition either restrict the size of the scanned objects or impose demands on the stability and structure of the surface. On the other hand, various society fields demand realistic 3D city models. For urban planning or historical buildings even ancient fortresses, analysing in a 3D virtual reality world is much more efficient than imaging the 2D information on maps. For public security, accurate 3D building models are indispensable to make strategies during emergency situations. Navigation systems and virtual tourism also benefit from realistic city models. Manual creation of city models is undoubtedly a rather slow and expensive procedure, because of the enormous number of buildings and complexity of building shapes. The rapid development of cities also adds to the cost of manual city model updating. Nowadays, a lot of research has been done to automate the procedure of city reconstruction, and a number of approaches have been proposed. These approaches differ with respect to input data, automation level, and object representation. In this context terrestrial 3D imaging laser scanning forms a method to acquire a large number of precise data points in 3D space representing the surface of the objects under investigation. These scanners are an effective tool for the collection of data to create a digital elevation model of the topography of a site as well as of the surface of a single archaeological deposit. The acquired data can be used for documentation purposes only, but the further processing provides the possibility for virtual reality modelling for public presentation, restoration planning or virtual reconstruction. Laser scanning technology and the final deliverable, materialized as the three dimensional model of the terrain, emphasises the importance and the applicability of geodesy in giving proactive solutions to architectural and engineering problems.
Keywords: laser scan, 3D modelling, digital reconstruction, cross-border project

INTRODUCTION

The RORS 394 project [1] aims at creating joint cross-border institutions for the promotion and maintenance of knowledge, and joint services of providing knowledge, primarily in the field of IT, as well as a rapidly growing industry, which contributes significantly to technological and sustainable inclusive development of the region. Raising the quality of education makes young people more employable; the collaboration between industry and institutions contributes to the adaptation of knowledge to the needs, and the existence of the place for informal education is an opportunity for these practice needs to be quickly transformed into knowledge.

Lifelong education through training of the trainers and online courses in the IT, entrepreneurship and management, contribute to the preservation and enhancement of the quality of knowledge which is a prerequisite for the sustainable inclusive growth, the growth based on the involvement and improving of knowledge of the local and regional participants.

In this context, different training sessions have been realized in Timisoara as follows: training in CNC programming (22-24.11.2019), training in Entrepreneurship (06-08.12.2019) and training in 3D scanning and printing (17-19.01.2020).

Three-dimensional data capture of objects on the Earth's surface is an important aspect of surveying and mapping, geospatial database construction, and 3D digital visualization. Currently, digital data acquisition is largely applied to 2D spatial databases. In this study, we present a new method that applies ground based laser scan survey and 3D digital building model construction. Previously, ground survey of spatial objects was mainly accomplished by a surveying total station. The method is relatively labour intensive and requires data conversions from analogue to digital to incorporate the results into a geospatial database [2].

3D scan data is useful in archaeology, paleontology and cultural heritage applications for dimensional analysis and study, providing a digital archival record, increased access to objects in remote locations, and to produce replicas useful for public exhibits. There is no way to record a complex

object than with a high resolution 3D scan. The fringe projection method used in white light scanning allows non-contact digitization of art and sculpture and historical artefacts. Direct comparisons can be made of dimension and shape. Scanning allows revisitation of any object over time, including redrawing of cross sections, 3D volume calculations, and other analysis that would otherwise prove to be very difficult if not impossible [3].

Figure 1. Photos from the training sessions realized in Timisoara

Traditionally, archaeological or architectural information is published in a monograph or book. But this kind of documentation cannot (or is more difficult to) be distributed economically and does not adequately depict the complex visual and technical data needed for study [4].

Vectorization is the process of making explicit, information in the raster image, by defining objects within the image using lines, arcs, closed polygons etc [5]. Vectorization of contours from a scanned topographical map is a complex procedure, requiring identification of features, rigorous image classification strategies and manipulation of spatial data structures like direction of line, boundaries and nodes, polygon vertices chain etc. the automatic extraction of contour lines from a scanned topographical map and its subsequent vectorization is one of the major research problems in computer cartography and GIS.

MATERIAL AND METHODS

— Mathematic method

In order to obtain 3D coordinates, we have to transform the coordinates from one system to another and there must be a connection between ellipsoids' origins and axes. From this information, the system origin translation in space X, Y, Z axis followed by rotation around X, Y, Z axis and the scale factor between the two ellipsoids can be determined. We denote the position vector of a point in space from the reference coordinate system XLOC and position vector of the same point in the secondary coordinate system with XGPS. Conform three dimensional transformation is described by the relation:

$$X^{LOC} = X_0 + mRX^{GPS} \quad (1)$$

I denoted with "m" the scale factor, with X_0 translation vector between the origins of the two systems, and the "R" rotation matrix which consists of three successive rotations around the coordinate reference system axes. With the rotation angles α_x, α_y, α_z the rotation matrix has general form:

$$R = \begin{pmatrix} \cos\alpha_y \cos\alpha_x & \cos\alpha_x \sin\alpha_z + \sin\alpha_x \sin\alpha_y \cos\alpha_z & \sin\alpha_x \sin\alpha_z - \cos\alpha_x \sin\alpha_y \cos\alpha_z \\ -\cos\alpha_y \sin\alpha_z & \cos\alpha_x \cos\alpha_z - \sin\alpha_x \sin\alpha_y \sin\alpha_z & \sin\alpha_x \cos\alpha_z + \cos\alpha_x \sin\alpha_y \sin\alpha_z \\ \sin\alpha_y & -\sin\alpha_x \cos\alpha_y & \cos\alpha_x \cos\alpha_y \end{pmatrix} \quad (2)$$

In order to solve the system, equation (1) must be linearized temporary values being needed for the unknown parameters. In the case of geocentric coordinate transformation into a national system of coordinates, there are some simplifications and the rotation matrix (2) becomes:

$$R = \begin{pmatrix} 1 & \varepsilon_Z & -\varepsilon_Y \\ -\varepsilon_Z & 1 & \varepsilon_X \\ \varepsilon_Y & -\varepsilon_X & 1 \end{pmatrix} = I + dR \quad (3)$$

Where: ε_X, ε_Y, ε_Z –the rotation angles differential sizes; I - unit matrix; dR - differential matrix.

Also, instead the vector containing the origin translations of the two systems, $X_0 = (X_0) + dX_0$ can be introduced, and (X_0) after the provisional values introduction for a single point "$m_0 = 1$" and "R0 = I" becomes: $(X_0) = XLOC + XGPS$. All this will be introduced in equation (1) resulting the relation:

$$X^{LOC} = (X_0) + dX_0 + (1 + dm)(I + dR)X^{GPS} \quad (4)$$

The Expression: $dX_0 + dm\ X^{GPS} + dR\ X^{GPS}$ – can be represented as a configuration matrix, A, which is multiplied by the unknowns' vector, which contains the dx transformation parameters, thus the equation becoming:

$$X^{LOC} = Adx + X^{GPS} + (X_0) \quad (5)$$

If there is no information regarding the terms size from provisional values vector for the translations (X_0), a zero size can be accepted and it results:

$$\begin{pmatrix} \Delta X_1 \\ \Delta Y_1 \\ \Delta Z_1 \\ \dots \\ \Delta X_m \\ \Delta Y_m \\ \Delta Z_m \end{pmatrix} = \begin{pmatrix} \Delta X_1^{LOC} - \Delta X_1^{GPS} \\ \Delta Y_1^{LOC} - \Delta Y_1^{GPS} \\ \Delta Z_1^{LOC} - \Delta Z_1^{GPS} \\ \dots \\ \Delta X_m^{LOC} - \Delta X_m^{GPS} \\ \Delta Y_m^{LOC} - \Delta Y_m^{GPS} \\ \Delta Z_m^{LOC} - \Delta Z_m^{GPS} \end{pmatrix} = \begin{pmatrix} 100.X_1.0 - Z_1 Y_1 \\ 010.Y_1.Z_1 0 - X_1 \\ 001.Z_1. - Y_1 X_1 0 \\ \dots \\ 100.X_m.0 - Z_m Y_m \\ 010.Y_m.Z_m 0 - X_m \\ 001.Z_m. - Y_m X_m 0 \end{pmatrix} * \begin{pmatrix} X_0 \\ Y_0 \\ Z_0 \\ m \\ \varepsilon_X \\ \varepsilon_Y \\ \varepsilon_Z \end{pmatrix} \quad (6)$$

with: $m \geq 3$, common points.

The system solving (6) leads to the seven unknown parameters determination X_0, Y_0, Z_0, m, ε_X, ε_Y, ε_Z. New points coordinate transformation determined only from satellite measurements will be now based on the seven parameters → X_0, Y_0, Z_0 (three translations), m (scale factor) ε_X, ε_Y, ε_Z (three rotations) with the transcalcul relationship from relation (1) [6].

RESULTS AND DISCUSSION

The case study refers to a residential building situated on 1 Decembrie 1918 Street, Timisoara municipality, an old building considered a historic monument. This building is located in a very frequented area by the citizens, being located near Balcescu Square and near "Grigore Moisil" theoretical high school. For this building, the terrestrial scanning operation (Fig. 2) was performed both before and after its rehabilitation.

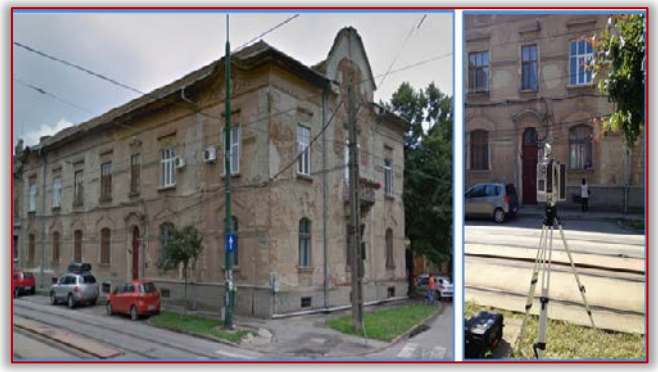
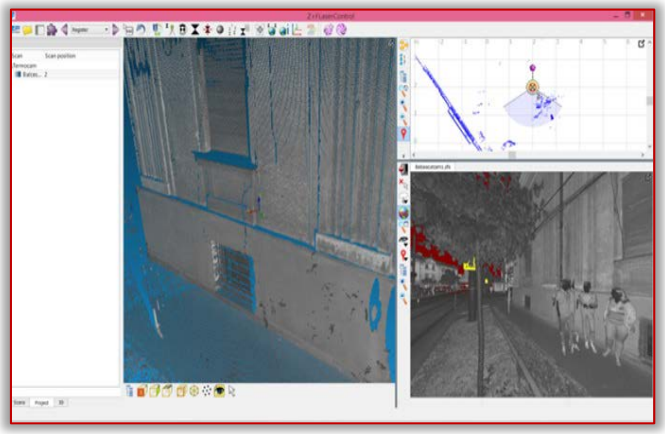


Figure 2. Historical building under study and laser scanner station's location

The scanning session lasted approximately 30 minutes, around 6 minutes for each scanning station. Data collected on field was stored on one of the two external hard-disks in order to be further processed at the office. Several stages of the 3D modelling process are highlighted:



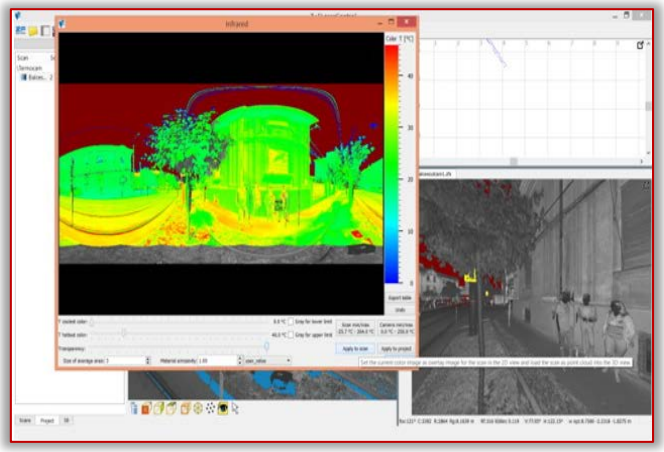
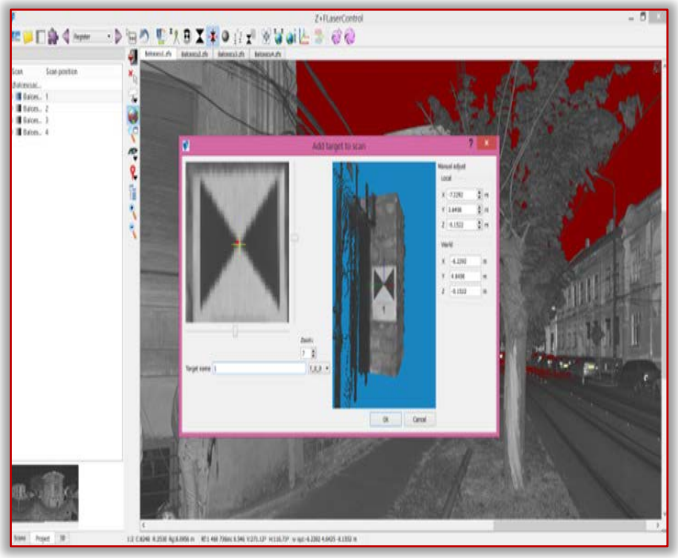


Figure 3. 3D View, Image space and station's sketch (top image) Temperature filters (bottom image)

The angle that the plane of the target with the laser beam should be neither not too obtuse nor too sharp, ideally 90o, but this is almost impossible for all targets. If registration quality is needed, the .png files are saved directly into the ".target" folder by the program.



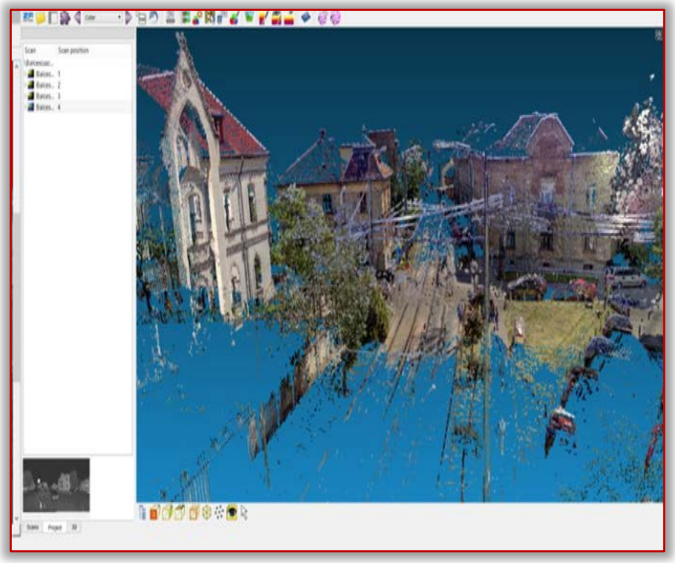


Figure 4. Manual registration of the targets (top image) Coloured point clouds (bottom image)

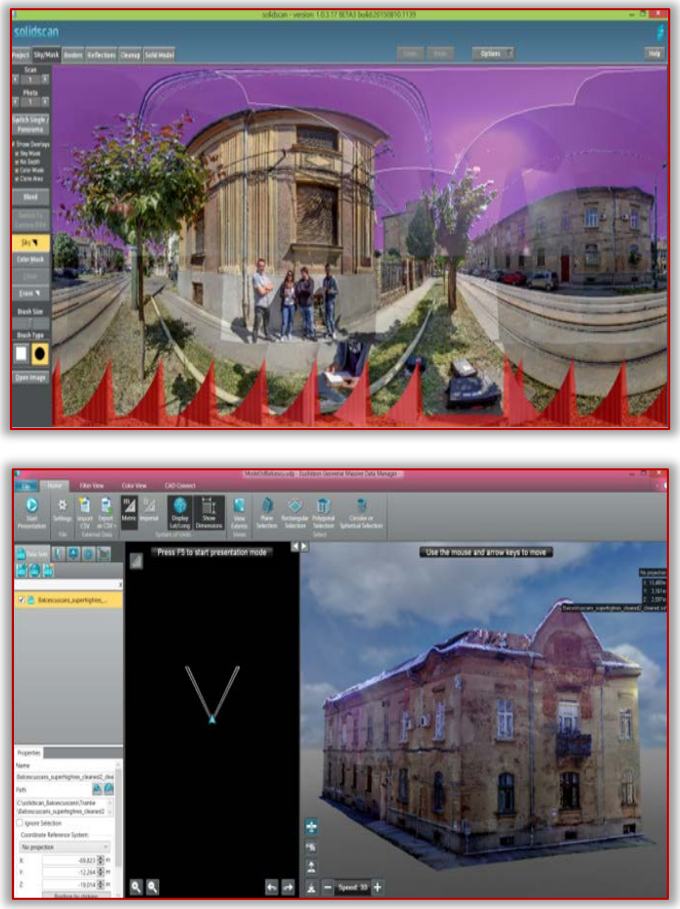


Figure 5. Reducing the noise – cleaning the point clouds (left image) Final 3D model (right image)

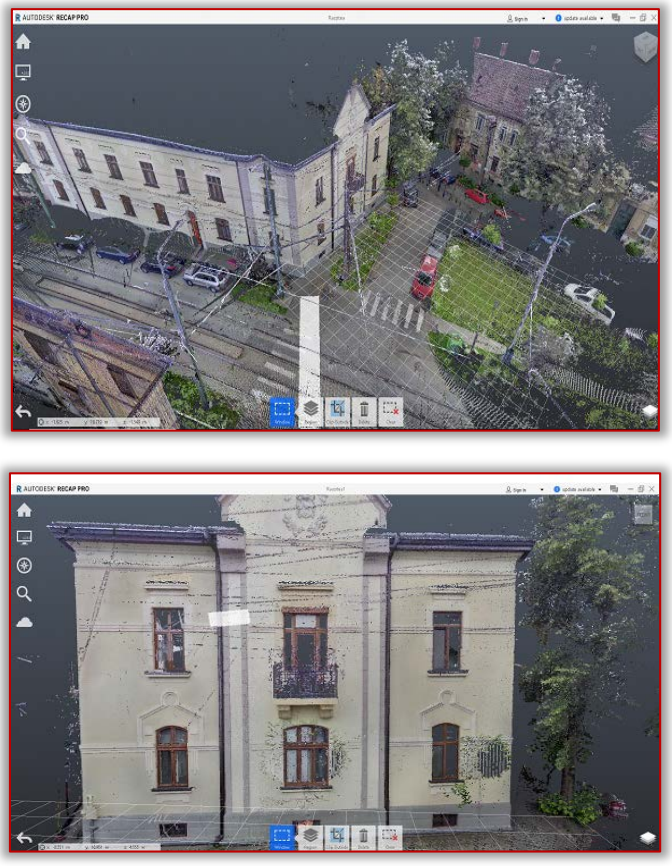


Figure 6. 3D model after the rehabilitation works

In order to realize a complete digital documentation, the cultural heritage building was also scanned after the rehabilitation works have been effected.

CONCLUSIONS

Comparing laser scanning method with traditional topographic surveys realized by total stations or with GNSS we can see that the later are much less expensive, offer very high accuracy but their application time is much higher. On the other hand, although laser scanning is much more expensive, it adds extra speed and efficiency to the surveying processes. At the same time, the amount of information received is far greater thus offering varied functionality to laser scanner data. Depending on the complexity of the work, the need for precision and the funds needed for a specific work, we can choose one method or another.

From the financial point of view, topographic methods are far cheaper than 3D laser scanning, since one of the cheapest scanners on the market along with the data processing software can be bought approximately with € 50,000. Instead, measurements can be made with any total station, or GNSSS receivers and their costs do not exceed € 10,000.

3D laser scanning technology can acquire 3D point cloud quickly with high accuracy. This meets the needs of historical architecture surveying and protection. 3D laser scanning technology can replace traditional measuring methods completely in historical architecture surveying. 3D point cloud can be gained by laser scanner, then construct the 3D model. In addition, detail structure can be got by close-range photogrammetry method, which produces the orthoimage and linear drawing [7].

Surveying of Historical architecture based on 3D laser scanning technology can not only reduce field work, improve efficiency but also provide different kinds of products such as 3D model, CAD construction drawing and so on. 3D laser scanner is growing towards high speed, high accuracy, large range and multi-information etc. at present. All these will impulse laser scanning application to historical architecture surveying and protection.

As regard the IPA project, it gave everyone involved the opportunity to work with educated adults who very easily mastered the information that was passed on and worked with visible enthusiasm, eager to improve. Thus, the project created the opportunity for teachers of different nationalities to interact and communicate, to exchange information, share ideas, feelings, research results. Moreover, the project answer to the challenges faced in academia at the moment, namely: the diversification of the student population and its needs, the rapid expansion of the use of technology, the motivation of students for learning, the pressure to develop new skills for future graduates, required by employers and the evolution of society.

The added value of the Cross Border dimension is reflected into the following:

— promoting multidisciplinary teams;
— promoting an integrated program for youngsters: training session, online platform and activities to support youngster in seeking jobs;

— promoting a favourable climate: emphasising that an environment which promotes innovation is a crucial requirement in order to attain goals in terms of technology and innovation;
— promoting motivation: increasing the motivation for youngsters and academic employees in universities and research institutions to enter into self-employment; Increasing the motivation for young people to develop entrepreneurial abilities and competencies in order to become independent (to enter into self-employment);
— promoting skills training and qualifications: strengthening knowledge and skills required in order to set up a business and manage a new company by consolidating the qualifications gained in schools and promoting further training.

Acknowledgment

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OVERVIEW ON GLAUCOMA DIAGNOSIS USING ARTIFICIAL INTELLIGENCE AND IMAGE PROCESSING TECHNIQUES

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Abstract: Today, glaucoma is the leading cause of blindness worldwide. In fact, the damage to the visual field is the major outcome of glaucoma. There are multiple goals of artificial intelligence in glaucoma. The first aim has been detection of glaucoma by classifying visual fields, optic nerve imaging, or other clinical data. Second, artificial intelligence has been utilized to detect worsening earlier than conventional algorithms. As the goal of its treatment is preventing the deterioration of the quality of life, detecting variations of the visual function on a time degree basis is principal for monitoring the effectiveness of the therapy. This paper presents an overview on glaucoma diagnosis using artificial intelligence and image processing.
Keywords: Diagnosis, artificial intelligence, image processing, ophthalmology, glaucoma

INTRODUCTION

Glaucoma is an eye disease that causes an irreversible decrease in the optical field. It is characterized by a progressive destruction of the optic nerve. The sufferer may become blind if he does not receive any treatment [1]. Besides, glaucoma is the second leading cause of blindness worldwide and mainly in least developed countries. One of the main signs of this lesion is the enlargement of the excavation of the papilla [2].

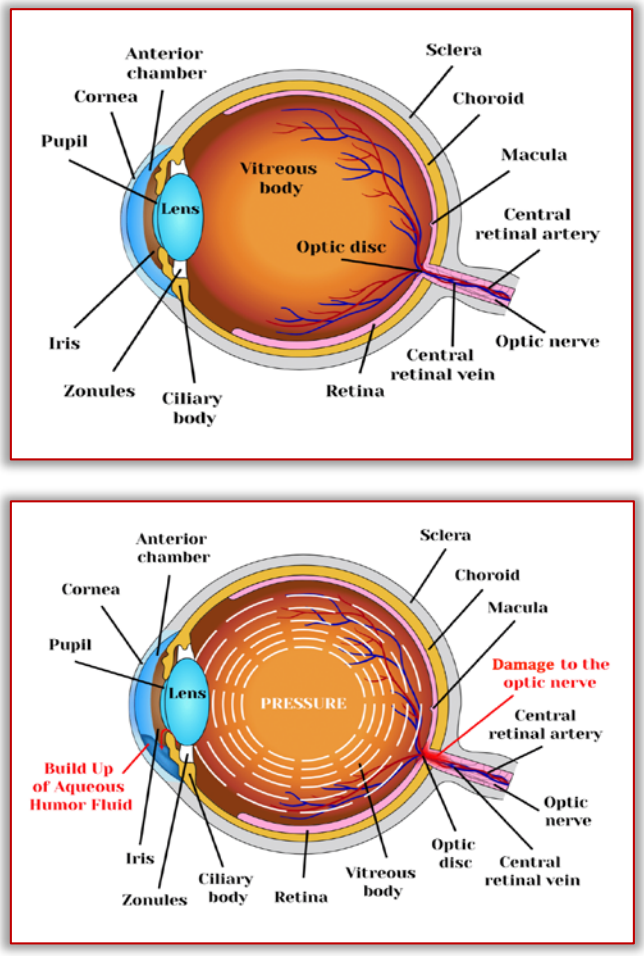

Figure 1. Comparison between normal vision and glaucoma

In fact, the papilla or the optical disc is the union of fibers which form the optic nerve, while the excavation is the depression observed in the optical disc characterized by the disappearance of the optical fibers [3]. The report "cup / disk", a report between the size of the excavation and that of the optical disk (normally around 0.3) tells us about the presence of glaucoma [4].

Generally, linear regression analysis and the other systems for detecting the glaucomatous functional progression rely on the dB deviation from normative data or on the probability estimate the loss has occurred in a given locus of the visual field [5], [6], [7].

Artificial intelligence and image processing have been widely utilized in glaucoma diagnosis. This paper presents a quick overview of the theme.

PART OF ARTIFICIAL INTELLIGENCE AND IMAGE PROCESSING

Since glaucoma is a group of eye diseases which result in damage to the optic nerve and cause vision loss. The most common type is open-angle (wide angle, chronic simple) glaucoma, in which the drainage angle for fluid within the eye remains open, with less common types including closed-angle (narrow angle, acute congestive) glaucoma and normal-tension glaucoma.

There are multiple goals of artificial intelligence in glaucoma. The first aim has been detection of glaucoma by classifying visual fields, optic nerve imaging, or other clinical data. Second, artificial intelligence has been utilized to detect worsening earlier than conventional algorithms.

Glaucoma increases the cup to disc ratio (CDR), affecting the peripheral vision loss. Many authors have addressed the various image processing techniques to diagnose the glaucoma based on the CDR evaluation of pre-processed fundus images [8], [9].

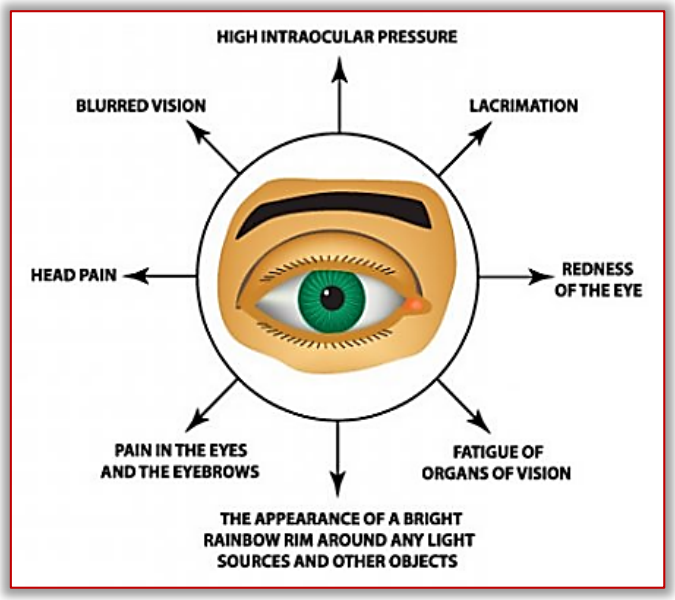

Figure 2. Symptoms of Glaucoma

Artificial intelligence (AI) is intelligence established by machines, unlike the natural intelligence displayed by humans and animals. Leading AI textbooks describe the field as the study of "intelligent agents": any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals [10], [11].

The field was founded on the assumption that human intelligence can be so in particular described that a machine can be made to simulate it. This raises philosophical arguments about the mind and the ethics of creating artificial beings endowed with human-like intelligence. Some people also think AI to be a danger to humanity if it progresses unabated others believe that AI, unlike earlier technological revolutions, will create a risk of mass unemployment [12], [13].

Digital image processing is the employ of a digital computer to process digital images through an algorithm. As a subcategory of digital signal processing, digital image processing has many advantages over analog image processing [14], [15]. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and distortion during processing. Since images are defined over two dimensions (perhaps more) digital image processing may be modelled in the form of multidimensional systems.

The generation and development of digital image processing are mainly affected by three factors:

- first, the development of computers;
- second, the development of mathematics (especially the creation and improvement of discrete mathematics theory);
- third, the demand for a wide range of applications in environment, agriculture, military, industry and medical science has increased.

Digital image processing technology for medical applications was inducted into the Space Foundation Space Technology Hall of Fame in 1994 [16], [17].

The emergence of artificial intelligence has influenced many aspects of our lives. Modern medicine relies profoundly on diagnostic tools using image processing algorithms and artificial intelligence.

REVIEW ON GLAUCOMA DIAGNOSIS

We present some studies of glaucoma diagnosis based on the use of artificial intelligence and image processing that have been presented in various researches:

Researchers Islam and Indiramma [18], have discussed the retinal vasculature conditions which they are important and reliable biomarkers for several cardiovascular and ophthalmologic diseases including Retinopathy of Prematurity, Diabetic Retinopathy, Glaucoma, Macular Degeneration, etc. The retinal-related diseases can be detected and diagnosed in the early stage before developing complexities and causing loss of sight by thoroughly understanding the vasculature condition.

Analysing these conditions is time consuming and tedious task. There have been many studies conducted to automatically extract retinal vessel information from fundus image and this is called retinal vessel segmentation. This paper provides a survey of the existing work that had been conducted to achieve this objective using Deep Learning methods. The authors have briefly discussed U-Net based network architectures proposed for object segmentation and the usage of these networks in medical fields for vessel segmentation. They have further compared the various architectures base.

Researchers Gabriel & al. [19], have proposed two different deep-learning based approaches to address glaucoma detection just from raw circum-papillary OCT images. The first one is based on the development of convolutional neural networks (CNNs) trained from scratch. The second one lies in fine-tuning some of the most common state-of-the-art CNNs architectures. The experiments were performed on a private database composed of 93 glaucomatous and 156 normal B-scans around the optic nerve head of the retina, which were diagnosed by expert ophthalmologists. The validation results evidence that fine-tuned CNNs outperform the networks trained from scratch when small databases are addressed. Additionally, the VGG family of networks reports the most promising results, with an area under the ROC curve of 0.96 and an accuracy of 0.92, during the prediction of the independent test set.

Researchers Chaima & al. [20], have presented modern ophthalmology which is not out of this context and has undergone a real revolution in recent years. Several studies have focused on combining artificial intelligence and image processing algorithms to provide powerful tools to assist ophthalmologists in their diagnoses and decisions. Recently, new devices combining these two sciences have been developed and the results seem promising. But where does the ophthalmologist stand in relation to this. The authors have tried to support the main scientific advances and describe the advantages, disadvantages and challenges.

Researchers Borwankar & al. [21], have automated the process of diagnosis of glaucoma using deep learning approaches. Image processing has gained a lot of attraction

and can be used for this problem in forming a computer-aided diagnosis for diseases. The authors have compared their results with previous approaches, which shows that our method has a better accuracy score.

Researchers Soltani & al. [22], have treated glaucoma disease which can affect the optic nerve head (ONH), thus causing its destruction and leading to an irreversible vision loss. The authors have presented a new glaucoma Fuzzy Expert System for early glaucoma diagnosis.

Original ONH images are first pretreated using appropriate filters to remove the noise. Canny detector algorithm is then used to detect the contours. Main parameters are then extracted, after having identified elliptical forms of both optic disc and excavation. This operation is performed by using Randomized Hough Transform. Finally, a classification algorithm, based on fuzzy logic approaches, is proposed to determine patients' conditions. The system is advantageous as far as it takes into consideration both instrumental parameters and risk factors (age, race, family history. . .) which make an important contribution to the valuable identification of cases suspected to have glaucoma. The proposed system is tested on a real dataset of ophthalmologic images of both normal and glaucomatous cases. Compared with other existing systems, the experimental results show the superiority of the proposed methods. The percentage of good predictions is more than 96%, reaching an improvement of 1–9% over earlier methods.

CONCLUSION

Glaucoma is termed as one of the most important causes of vision loss and in many cases is irreparable. It is a condition that damages the optic nerve and it goes ignored in early stages as the symptoms are not prominent in the early stages. In conclusion, the evaluation and description of the development of the functional damage is a fundamental variable in the management of patients suffering from glaucoma.

Recent approaches have been made to automate the detection of glaucoma based on available datasets. So artificial intelligence and image processing have been widely utilized in glaucoma diagnosis.

Staring from this overview on glaucoma diagnosis using artificial intelligence and image processing presented in this paper, work is in progress to develop a system analysis for glaucoma diagnosis for decision-making based on images in the medical field.

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SWEET SORGHUM CULTIVATION IN BLACK SOIL AND PHYTOMELIORATED ROCKS IN UKRAINE

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Abstract: A comparative analysis of the prospects for growing sweet sorghum Silosne-42 on the zonal soils and mining substrates brought to the surface during process of manganese ore mining in the steppe zone of Ukraine (loess-like loam, red-brown clay and gray-green clay) is performed. The best above-ground biomass productivity was shown on loess-like loam. The highest content of soluble sugars in the stem juice was found in samples grown on zonal black and loess-like loam (15.8–16%), and the smallest on green-grey clay (14.8%). Cultivar Silosne-42 has good potential for the production of bioethanol, the theoretical yield of which ranged from 1019.5 L ha^{-1} to 1454.5 L ha^{-1}.
Keywords: sweet sorghum, biomass yield, ethanol yield potential, black soil, rock phytomelioration

INTRODUCTION

Because of energy crisis increase all over the world, the acute problem of alternative energy source search appears before humanity. In Ukraine, there are favorable conditions for the production of biofuel from agricultural raw material. Many crops are used as feedstock for renewable energy. For instance, briquetted straw of wheat, rye, oats, sunflower is used to produce heat and electricity. Silage corn, rape, mustard, and flax are raw materials for diesel fuel. Plants containing a large amount of soluble sugars (corn, wheat, potatoes, topinambour, sugar beet, sorghum) are used to produce bioethanol (*Geletukha et al., 2014*). However, for the cultivation of energy crops, it seems more appropriate to use lands that are not suitable for classical farming: unproductive, clayey, saline, or even polluted by the economic activity of mining and processing facilities. In this regard, the urgent issue is the search of plants that can successfully grow and produce stable yields in such conditions. Sweet sorghum is a promising crop for obtaining cheap bioethanol on marginal lands. It has several advantages over other cultures.

First of all, sorghum is notable for high drought and salt tolerance. Leaves and stems of sorghum are covered with a wax bloom, which reduces evaporation. In addition, this plant is poorly damaged by pests. Sorghum removes salts from the soil; it transfers hard-to-reach forms of phosphorus to more accessible ones and draws readily available phosphates from a 1.5-2-meter layer of soil to 30-50 centimeter layer *(Reddy et al., 2007; Dalla Marta et al., 2014)*. The sweet sorghum includes a large number of cultivars that are remarkable by a high content of soluble sugars in stems (from 10 to 20%). The sugars in stems mainly comprise sucrose (about 80-85%) with some amount of fructose, glucose (about 12-15%) and starch (about 3%). In comparison to lignocellulosic biomass polysaccharides these sugars are readily fermentable (Almorades & Hadi, 2009; Wang et al., 2012; Regassa & Wortmann, 2014). Sweet sorghum serves as a raw material for the production of syrup, crystalline sugar, ethanol, methane, is used for ensiling and obtaining green mass. The yield of sugar from sweet sorghum can reach 5-7 t ha^{-1}, ethanol 3000-5000 L ha^{-1} (*Zhao et al., 2009; Kim & Day, 2011*).

Sorghum takes the fifth place in the world among cereals after corn, wheat, rice and barley. The main producers of sorghum are the USA (10 million tons yearly), Nigeria (10.5 million tons), India (7.8 million tons), and Mexico (5.5 million tons). In Ukraine sorghum is grown mainly in the steppe southern and central regions. A significant part of the steppes is concentrated in the zone where 400-450 mm of annual precipitation falls, and the sum of effective temperatures is optimal for sorghum cultivation. Sweet sorghum can be grown as monoculture for 3-5 years without loss of yield, provided proper protection against weeds and compensation for nutrient removal.

Unpretentiousness of sorghum to soil conditions makes it possible to use low-productive and unproductive lands for cultivation of this crop (*Ren et al., 2012; Fu et al., 2016*). Today in Ukraine, out of 32 million hectares of agricultural lands, 8 million hectares are unproductive. In addition, in industrial southeastern and central regions, as a result of mining and processing of minerals, huge areas are formed, which are wastelands with sites of destroyed soil and large volumes of mining wastes and empty rocks brought to the surface. Even after many years of reclamation, these technogenic lands differ significantly from zonal soils in the level of fertility, physical, chemical, agrochemical and other important ecological indicators, and therefore they are of little use for the cultivation of many crops. At the same time, the growing of energy crops, including sorghum, in such territories may prove promising and economically viable.

MATERIALS AND METHODS

The sweet sorghum cultivar Silosne-42 was studied. This variety was bred in 2003 at the Dnipro Institute of grain farming for obtaining green biomass, silage and sugar syrup. Its main characteristics are shown in Table 1.

Table 1. Morphological characteristics of sweet sorghum cultivar Silosne-42

Height, cm	Number stem per plant, pieces	Panicle form	Seed features	Growing season, days	Potential productivity of green biomass, t ha^{-1}
220-250	2-3	ellipsoid	large, brown	105-115-(wax ripeness) 120-125-(full ripeness)	55.0-76.0

The research was conducted at two sites: at Pokrov land reclamation station of Dnipro State Agrarian and Economic University and Sinelnikovo selection and experimental station of the National Academy of Agrarian Sciences of Ukraine. Geographically, both stations are located in the Dnipropetrovsk region in the steppe zone of Ukraine with moderately continental climate (hot summer and moderate winter). This zone is characterized by unstable water supply and frequent prolonged droughts during the growing season. The average hydrothermal coefficient is 0.9. In recent years, there has been a gradual increase in the average monthly air temperature with a simultaneous decrease in the amount of precipitation. The zonal soils (ZS) at the Sinelnikovo experimental station are quite homogeneous and consist mainly of ordinary low-humus full-profile black soils eroded to varying degrees. Specific gravity of these soils varied from 1.0 to 1.2 g/cm^3, total content of argillaceous fraction minerals is 28-35%, humus content is 3.4-3.5%, the level of the lowest moisture capacity is 27.2-31.0%.

Pokrov land reclamation station of Dnipro State Agrarian and Economic University is located in the Nikopol manganese ore deposit. The rocks of this ore basin were brought to the surface during process of manganese ore mining. The soil mass was taken off, piled up and heaped onto the land after the rock was replaced. Substrates formed in this way can be attributed to the category of Technosol which are soils strongly influenced by human activities, and as a result, their properties and pedogenesis are dominated by technical origin (De Kimpe & Morel, 2000). For experience were used three types of mining substrates taken from the board of the quarry and exposed to long-term soil stabilization: loess-like loam, (LLL), red-brown clay (RBC) and green-grey clay (GGC). The total content of argillaceous fraction minerals in these substrates varied from is 23.5 (LLL) to 63.5% (GGC), humus content is low (1.05-1.25%), maximal hygroscopicity level 7.6 (LLL)-20.5% (GGC).

Biometric indices, productivity, brix, conservative sugar yield, and theoretical ethanol yield were studied. The plant height was measured using a measuring line. To determine the yield of above-ground biomass, plants were harvested after the grain reached milky ripeness stage by cutting at the height of 10 cm from the ground level and weighed. After that, the biomass was dried to constant weight, and then weighed again. Brix was determined using a hand-held refractometer "RHBO–50ATC".

Conservative sugar yield (t ha^{-1}) was calculated based on an approach assuming that the sugar concentration is 75% of Brix expressed in g kg^{-1} sugar juice (Wortmann et al., 2010; Ekefre et al., 2017). It was used the equation: CSY= (FSY–DSY)*Brix*0.75. Where, CSY is conservative sugar yield (t ha^{-1}), FSY is fresh stem yield (t ha^{-1}), DSY is dry stem yield (t ha^{-1}). Theoretical ethanol yield was calculated as sugar yield multiplied by a conversion factor (0.58 L ethanol per kg of sugar): TEY=CSY*0.58 (Rutto et al., 2013; Ekefre et al., 2017). Where, TEY is theoretical ethanol yield (L ha^{-1}), CSY is conservative sugar yield (kg ha^{-1}).

RESULTS

A comparative analysis of the sweet sorghum cultivation on zonal soils and mining substrates showed some differences in biometric indicates depending on the type of soil. The tallest plants were noted on the loess like loam, the lowest on the green-grey clay (table 2). The disparity amounted 8-25%.

Table 2. Height of sweet sorghum Silosne-42 grown on different substrates, cm

Type of substrate			
ZS	LLL	RBC	GGC
222.0±2.31	240.3±4.50	212.9±2.43	203.0±2.87

In general, plants grew and developed better on loess-like loam and on zonal soil. As a result, the yield of biomass on these substrates was higher than on red-brown clay and green-grey clay (fig.1).

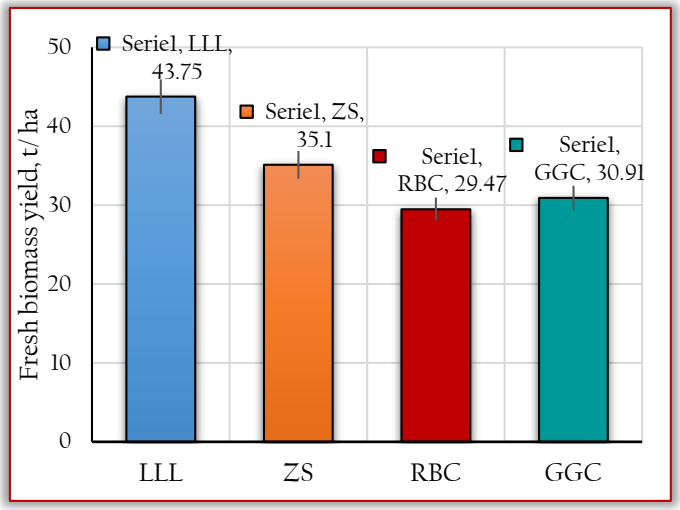

Figure 1 Biomass yield of sweet sorghum Silosne-42 as affected type of soil

The percentage of juice in the stems was the highest in plants grown on zonal soil (51.43%), and the lowest in plants grown on loess-like loam (47.36%). At the same time, the highest content of sugars in the juice was noted on this substrate. In other variants of the experiment, this index was lower by 1.3-7.5%. In consideration of productivity and sugar

content, the conservative sugar yield on loess-like loam was higher than on other substrates by 14.0-30.1% (table 3).

Table 3. Brix and conservative sugar yield (CSY) of sweet sorghum Silosne-42

Parameters	Type of substrate			
	ZS	LLL	RBC	GGC
Brix, %	15.8±0.22	16.0±0.23	15.6±0.21	14.8±0.11
CSY, t ha^{-1}	2.14±0.04	2.49±0.04	1.75±0.02	1.74±0.02

The biomass yield and percent juice extracted are the best predictors of potential ethanol yield per area. This index was between 1454.5 L ha^{-1} on loess-like loam and 1019.5 L ha^{-1} on green-grey clay (fig.2).

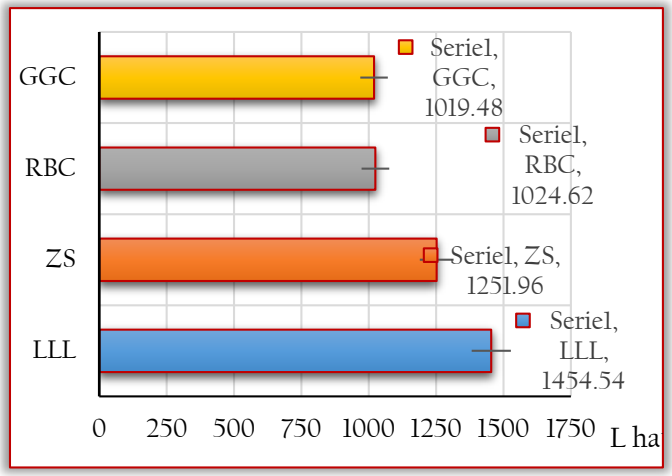

Figure 2. Potential ethanol yield per area in sweet sorghum Silosne - 42 (L ha^{-1})

According to different data (Macesic et al., 2008; Kim & Day., 2011; Ekefre et al., 2017), depending upon the various factors, the ethanol yields from the sweet sorghum fermentable sugars vary within a wide range, from 750 to 5800 L ha^{-1}. Our data are quite conform to those obtained by others and can be considered economically viable.

CONCLUSION

Sweet sorghum, with its low input requirements, is one of the leading candidates for growing on reclaimed mining lands as a biofuel feedstock. Domestic breeding cultivar Silosne-42 showed the highest productivity of biomass on loess-like loam. Thus, soil fertility is not a limiting factor for the accumulation of sorghum biomass. Despite the low humus content, loess-like loam has favorable agrophysical and agrochemical properties. The presence of calcium carbonate determines the water and air permeability. These properties were probably more important for growth processes. Sweet sorghum Silosne-42 has a good potential for bioethanol production at cultivation both on the zonal soils, and on meliorated mining substrates. Although the highest yield of ethanol was obtained on loess-like loam and zonal black soil, red-brown and green-grey clays are also quite suitable for growing this cultivar as a feedstock for the production of this biofuel type.

Note:
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RESEARCH ON ROOTING PELARGONIUM CUTS USING DIFFERENT TYPES OF SUBSTRATES

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Abstract: The geraniums are rich in flowers, brightly colored, with rounded leaves and slightly fragrant. These are known scientifically as Pelargonium. It is distinguished by the fact that it has irregularly shaped flower buds, fewer fertile stamens and a tube of nectar, compared to other species in the Geraniaceae family. Pelargonium plants are widely used for decorative purposes, both inside and outside our homes. The genus Pelargonium comprises about 300 species and varieties of perennials, most of which are native to South Africa. These plants are part of the Geraniaceae family. The geranium is a plant, able to bloom continuously from May until the appearance of the first autumn frosts, provided that they benefit from a strong sunshine and a moderate watering. The establishment of the experiment was intended to obtain a culture technology of these plants, as optimal as possible, in order to provide scientific information, mainly to flower producers, but also to enthusiasts of this branch. The experiment was set up at the Buzau Vegetable Research and Development Station in the fall of 2019. This experiment involved making twelve cuttings of Pelargonium Calliope Dark Red, which were placed in different soil substrates.
Keywords: cuttings, rooting, Pelargonium, substrate

INTRODUCTION

The geraniums are rich in flowers, brightly colored, with rounded leaves and slightly fragrant. These are known scientifically as Pelargonium. It is distinguished by the fact that it has irregularly shaped flower buds, fewer fertile stamens and a tube of nectar, compared to other species in the Geraniaceae family.

The flies are of different sizes, from 30 to 100 cm high, with various shapes of flowers and leaves, more intense or less colored. Licorice can have the scent of mint, pine, cinnamon, lemon, pineapple, orange, etc. The genus Pelargonium (The Geraniaceae family), with more than 200 species, has considerable economic importance on the ornamental plant market (*García-Sogo et al., 2012*). Geraniums are popular pot plants with attractive flowers, a wide range of colors, flowers, blooms and leaves *(Kheenizy, 2016)*. Pelargonium, as balcony plants, has a relatively high nutrient requirement *(Farkas Zsuzsa et al., 2018)*.

The family groups numerous grass species, which have aerial organs covered with glandular bristles, which produce ethereal oils with repellent effect against biotic factors (phytophagi) (Tomescu, 2020). Pelargonium species are important in the perfume industry and are grown and distilled for their fragrance *(García-Sogo et al., 2012)*. The stems are branched, swollen at knots, erect or ascending, with alternating or opposite leaves, simple or composed, accompanied by stipes. Flowers are actinomorphic or zigomorphic, hermaphrodite, type 5, solitary or arranged in umbels *(Tomescu, 2020)*.

Geraniums multiply vegetatively through cuttings of stems (Toma, 2020). The cuttings are obtained from the mother plant by segmenting the stems, being under observation for a period of time, with a view to rooting *(Molenaar et al, 2017)*. The absence of symptoms of senescence in the leaves of Pelargonium cuttings, their ability to root, grow and develop harmoniously and not in the end the absence of diseases and pests, represent the impoetante quality criteria *(Mutuia et al., 2012)*.

The storage of cuttings in dark areas for certain periods of time had no effect on the percentage of rooting and the number of roots. In some species, dark storage reduced the total root lengths and reduced the mass of the fresh root *(Mutui et al. 2010)*.

The addition of zeolite induced a considerable increase in Tagetes sp and improvement of germination, number of plants and flowers to hybrids of Gladiolus sp. *(Kolar et al 2010)*

Buzău is located in the southeastern region of Romania, in the central area of Buzău County, on the right bank of the Buzău River, at an altitude of 101 m above sea level, with coordinates 45°09" north latitude and 25°5" east longitude *(https://www.primariabuzau.ro)*

Calliope Dark Red, the specific color of this geranium is dark red, large, round plant, flower shape is of very rich medium size, compact semi-flowing growth with a very good branching *(Toma, 2014)*. It is a hybrid of geranium, super vigorous plant, particularly attractive in suspended pot, loves light. Flowering is extremely abundant. Dress the edges very well *(Toma, 2014)*.

The establishment of the experiment was intended to obtain a culture technology of these plants, as optimal as possible, in order to provide scientific information, mainly to flower producers, but also to enthusiasts of this branch.

MATERIALS AND METHODS

The experiment was set up at the Buzau Vegetable Research and Development Station in the fall of 2019. This experiment involved making twelve cuttings of Pelargonium Calliope Dark Red, which were placed in different soil substrates, as follows:

- water, biostimulator solution - Atonik, perlite,
- perlite + Micoseeds (prepared for rooting stimulation),
- sand + peat + perlite + Micoseeds,
- sand + peat + perlite,
- sand + Micoseeds,
- sand + peat + Micoseeds,
- sand, peat + sand,
- peat + Micoseeds,
- peat.

The plants were exposed to the following environmental factors: temperature 18-20 degrees Celsius, moderate humidity, positioned in a very well lit area. Observations were made on the twelve plants 25 days after the establishment of the experiment.

Figure 1- Preparing Calliope Dark Red Geranium Cuttings at SCDL Buzau, 2019

For the purpose of experimenting, it was chosen to choose vegetable matter, a hybrid with a semi-flowing port, with flowers of an intense red and a rich bloom (Calliope Dark Red). As can be observed in Figure 1 A, the experiments have made plant propagation material (mother plants), these being the source of obtaining new plants by a well-established process, as can be seen in Figure 1 B and C, the end of the process being the obtaining of quality cuttings, from a plant protection and vegetative point of view. Prepare the Calliope Dark Red geranium cuttings by cutting. A cutting, according to the quality standards of the plant propagation material, was between 8-10 cm long or about 3 knots. Basically, cut about 60-70% of the plant (Toma, 2014).

RESULTS

Based on research carried out on the vegetative propagation plant material of the genus Pelargonium, it was found that cuttings belonging to this genus root in a shorter period of time, in the following substrates or combinations of substrates, in the order presented

1. Sand + peat +perlite;
2. Peat +micoseed,
3. Peat,
4. Sand. (Figure No 2).

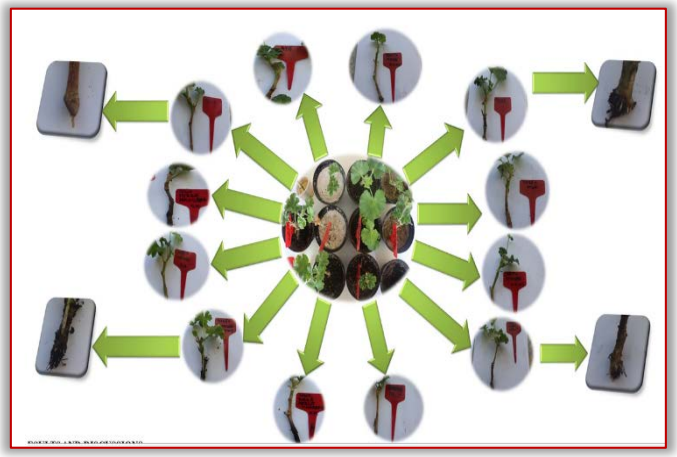

Figure 2. Rooting of Calliope Dark Red geranium cuttings

Rooting of Calliope Dark Red geranium cuttings, use the following substrate variants/substrate combinations:

- water, biostimulator solution - Atonik, perlite,
- perlite + Micoseeds (prepared for rooting stimulation),
- sand + peat + perlite + Micoseeds,
- sand + peat + perlite,
- sand + Micoseeds,
- sand + peat + Micoseeds,
- sand, peat + sand,
- peat + Micoseeds,
- peat.

In order to obtain healthy plants, according to the quality standards of the plant propagation material, research has been done on the establishment of the most optimal environment and substrate of culture to shorten the period of rooting of cuttings, a process that influences the period of plant vegetation. Following the establishment of optimal conditions and substrates for the rapid rooting of cuttings the recovery period, which is very important for manufacturers is considerably reduced.

(a)

(b)

Figure 3- Geranium seedlings (a) *(Toma, 2019)*.
(b) Detail geraniums *(Toma, 2019)*.

After performing the process on the mother plants, the new cuttings were obtained which were planted in alveolar pallets, benefiting from a nutrient substrate suitable for the new plants, a factor that helps the optimal vegetative development of the plant, as can be seen in image 3A. The post-walking work of this process is successive transplantation into vessels suitable for the size of the plant, as shown in image 3B.

Figure 4- Rooted geranium cuttings, ready to plant in pots *(Toma, 2019)*.

The optimal time of transplantation of rooted cuttings is determined according to several characteristics: when their roots begin to develop circularly at the base of the vessel and when the leaf surface begins to develop, as can be seen in the image above (Figure 4). In the case of cuttings with very long and thin roots, the cutting work is carried out, which helps to catch and develop the new plant.

CONCLUSIONS

Observations were made on the twelve types of plants 25 days after the establishment of the experiment. Pelargonium cuttings have visibly taken root 25 days after planting, in certain substrates, the root being vigorous and with visible signs of branching (over 1 cm in root length).

The experiment was set up to establish a substrate (or combination of severMal substrates), suitable for a more efficient rooting of these plants, which can be used frequently by growers.

Acknowledgement

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Note:

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A SEPIC-CUK-CSCCC BASED SIMO CONVERTER DESIGN USING PSO-MPPT FOR RENEWABLE ENERGY APPLICATION

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Abstract: This paper presents the operation of Single Input Multiple Output (SIMO) converter using the SEPIC-Cuk-Canonical Switching Cell Combination Converter (SEPIC-Cuk-CSCCC) topology, supplied from a Solar Photo Voltaic (SPV) source. As the output of the SPV depends on the ambient condition like solar radiation and temperature, a Particle Swarm Optimization (PSO) based Maximum Power Point Tracking (MPPT) method is applied to maintain the SPV operating point at Maximum Operating Point (MPP) always. This SIMO converter produces three different output voltage (both positive and negative polarity). Reduced converter size and the cost with higher efficiency can be achieved in this topology as only one controllable switch along with less number of components is used. A simulation has been carried out to verify the operation of the PSO-MPPT based SIMO converter. Simulation results show satisfactory MPPT operation. Besides, it is also shown that for SIMO applications, a combination of Single Input Single Output (SISO) converter is preferable.
Keywords: PSO-MPPT, SPV application, SIMO converter, DC-DC converter

INTRODUCTION

To meet the growing power demand without any environmental issues, renewable energy sources are the most eligible option in the recent era. Continuous decrement of the cost of the Solar Photo Voltaic (SPV) makes itself more valuable for future research and implementation [1]. Besides that, the SPV system has the advantages of the absence of rotating parts, minimum maintenance, and almost zero environmental loss [2], [3].

The power characteristics of the renewable energy source are nonlinear in nature because of the dependency on solar irradiance, ambient temperature. There exists one operating point where they generate maximum power which is observed in the solar P-V and the V-I characteristics. In order to take full advantage of available energy resource and achieve maximum utilization efficiency, maximum power point tracking (MPPT) control techniques which extracts maximum power from the renewable source is essential. Several researchers prescribed different MPPT methods for extracting maximum power[4]. Based on the involvement of several control variables, types of control strategies, nature of the available circuitry, and cost of applications are the main factors to select the MPPT algorithm.

The evolution of developing DC-DC converter has been constant over the past year. The requirement of different voltage and power level across the power electronics devices in different applications enhances the growth of the development of the DC-DC converter. So not only the single quadrant converter, multi-level and multi quadrant converter has become famous day by day for its new control strategy and topologies, which cause the efficiency improvement and the reduction of size.

There are a variety of applications where multiple dc outputs with different voltage levels are required from a single power supply as step-up, step-down, and sometimes both step-up/down mode.

For such application, a multi-port DC-DC converter provides the best solution. Single input multiple output (SIMO) converter is one of the well-known multi-port converter used for such application. i.e. Hybrid/ Electric Vehicles (EHV), microelectronics, telecommunication, lighting, etc. Increased efficiency with reduced cost can be achieved in the SIMO converter as less number component is used.

In this paper, a SEPIC Cuk CSC combination converter-based SIMO converter, connected with a SPV is proposed where a single switch is shared by all of these converters which provides simplification in control. A Particle Swarm Optimization (PSO) based MPPT control is implemented to extract maximum power from the SPV. In the proposed converter SEPIC converter provide positive voltage output. Besides this Cuk and CSC converter produced a negative output voltage. A simulation model is developed in MATLAB/Simulink software and the verification of PSO – MPPT based SIMO converter output is verified.

This article mainly focuses on the operation and design PSO-MPPT based SEPIC Cuk CSC converter. The complete structure of the proposed topology is described in section 2. The PSO based MPPT algorithm along with the converter working are discussed in section 3. Section 4 describes the control analysis of the proposed topology.Simulation results are shown in section 5.

PROPOSED TOPOLOGY

In [5]–[7], basic topologies of the non-isolated converter is introduced for solar PV application. Besides the conventional topologies, a combination of these converters can sometimes found advantageous in many applications as given in [8]–[10]. A comparative study of different MPPT techniques for a basic converter with their performance analysis is also described in [4]. PSO based MPPT algorithm is preferred over conventional technique like perturb and observe (P and O) and incremental conductance (IC).

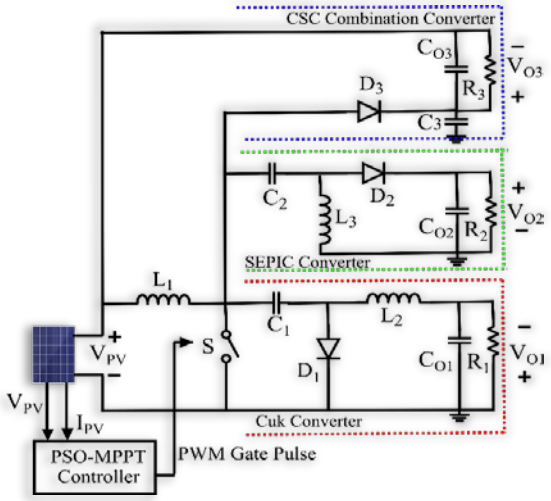


Figure 1. Proposed SEPIC-Cuk-CSC Converter

In this paper, a SEPIC-Cuk-CSC combinational SIMO converter is proposed (fig 1) where a PSO based MPPT technique is applied to extract maximum solar PV power.

OPERATING PRINCIPAL

— PSO – MPPT Algorithm

Particle Swarm Optimization (PSO) is a population-based intelligence optimization technique, inspired by the foraging behavior of a flock of birds and fish schooling in search of food. In PSO algorithm individual birds are referred to as an individual flying particle that has its own fitness value. Each particle movement, in terms of direction and distance, as calculated by the objective function and the velocity of the individual particle. Exchange of information between the particles happened based on their search process. P_{best} and G_{best} are the best position of the individual particle and the best position of the all the particle, comparing all the P_{best} , respectively. All the swarm updates their direction and velocity to move towards the best position. So, the convergence can be achieved[11]–[13]. The standard PSO algorithm can be represented by

$$v_i(k+1)=wv_i(k)+c_1r_1\left(P_{best}-x_i(k)\right)+c_2r_2\left(G_{best}-x_i(k)\right) \quad (1)$$

$$P_{best}=x_{ik} \quad (2)$$

$$f\left(x_{ik}\right)>f\left(P_{best,i}\right) \quad (3)$$

$$x_i(k+1)=x_i(k)+v_i(k+1) \quad (4)$$

where $i=1,2.....N$. v_i and x_i are the velocity and the position of the particle i , the number of iteration denoted by k, w represents the inertia weight. r_1 and r_2 are the uniformly distributed random variable within [0 and 1]. Cognitive and social coefficients are denoted by c_1 and c_2 . P_{best} and G_{best} represent the individual best position of i^{th} particle and the swarm best position of all the particle. If equation 5 is satisfied then the value of the P_{best} can be updated by equation 6.

$$f\left(x_{ik}\right)>f\left(P_{best,i}\right) \quad (5)$$

$$P_{best}=x_{ik} \quad (6)$$

where, f represents the objective function that should be maximized.

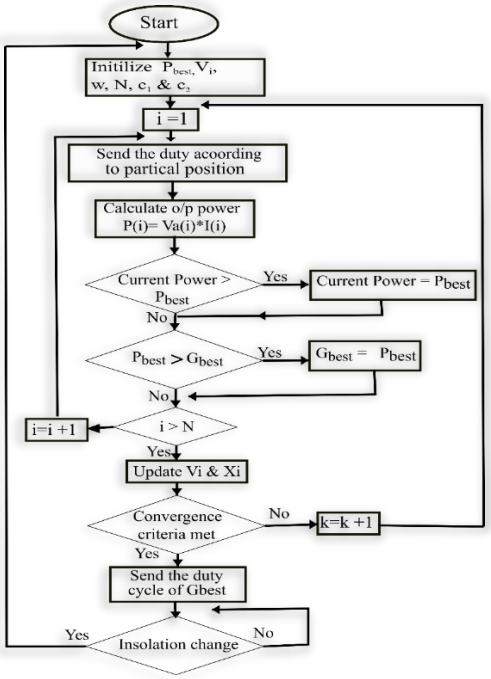


Figure 2. PSO based MPPT algorithm flowchart.

In Figure 2, the PSO based MPPT topology is described. As given in the flowchart at the beginning particle swarm position and fitness value evaluation function are defined as the duty cycle and the generated output power respectively. A random initialization, within a uniform distribution, is made for the position and the velocity of each particle. After that the fitness value of the particle is calculated, it is updated comparing with the previous value. P_{best} and G_{best} of each particle are also update against the previous values. Thereafter particle velocities and positions are updated accordingly.

With the new value of v_i and x_i , the convergence criteria are checked, which are either optimal solution localization or reaching the maximum number of iteration. Depending upon the weather condition and the load value, the fitness function becomes variable. So, the PSO must be reinitialized to search a new MPP as the output of the PV module changed.

— Single Input Multiple Output(SIMO Converter)

In this section, an interesting combination of SEPIC Cuk CSC combination converter topology is introduced. The ability to produce both positive and negative voltage simultaneously makes this converter topology suitable for renewable energy-based dc bipolar network applications. As given in Figure 1 the CSC converter and Cuk converter produce a negative voltage whereas the SEPIC converter produces a positive voltage at the load output terminal.

≡ SEPIC converter:

The Single-Ended Primary Inductance Converter or SEPIC converter is a modification of a non-isolated DC-DC converter. Some of the features, which makes this converter suitable for the PV application, are given by[14], [15]

- Non-inverted output.
- The input inductor provides a low input ripple and noise.

- Multiple inductors can be a couple in the same core.
- Galvanic isolation can be easily obtained by replacing one of the inductors by a high-frequency transformer.

The conventional SEPIC converter is shown in Figure 3 Where Vg is termed as an input dc voltage source. A MOSFET can be used as switch S, which is having a duty cycle of D.

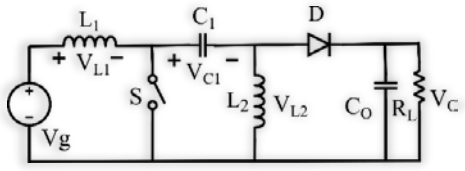


Figure 3. SEPIC Converter topology

In continuous conduction mode, the SEPIC converter operates in two different modes shown in Figure 4a and 4b. In mode (a) when the switch S is turned on (duration is giving by $0 \le t \le DT$, Where T represents the time period of the gate pulse), both the inductor current (I_{L1} and I_{L2}) are increasing because of charging and no energy is transferred to the load as D became reversed biased. In mode (b), when the switch S is turned off (duration given by $DT \le t \le T$), the D becomes forward biased and the energy is transferred to the load as both the inductor (I_{L1} and I_{L2}) are now discharging

The volt-second balance across the inductor L_1 and L_2 given by

$$V_g DT + \left(V_g - V_{C1} - V_D - V_O\right)(1-D)T = 0 \quad (7)$$

$$V_{C1} DT + \left(-V_O - V_D\right)(1-D)T = 0 \quad (8)$$

where V_D represents the voltage drop across the diode.

The output of the SEPIC converter is represented as

$$V_O = \frac{DV_g}{(1-D)} \quad (9)$$

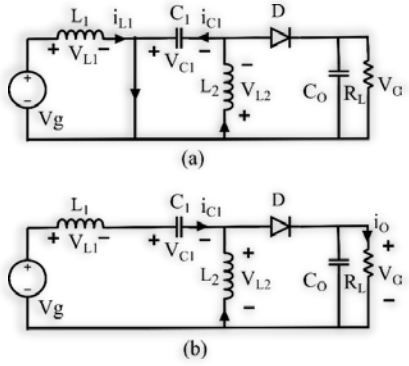


Figure 4. Operation of SEPIC converter. (a) When S is turned on. (b) When S is turned off.

The value L_1, C_1 and L_2 of the SEPIC converter can be calculated by [16]

$$L_1 = \frac{V_g D}{\Delta I_{L1} . f_s} \quad (10)$$

$$L_2 = \frac{V_g D}{\Delta I_{L2} . f_s} \quad (11)$$

$$C_1 = \frac{V_O D}{R_L \Delta V_O f_s} \quad (12)$$

≡ **Cuk Converter:**

Cuk converter is a cascaded combination of the basic boost converter and buck converter with a coupling capacitor. The basic structure of the Cuk converter is given in Figure 5. Energy is transferred from the input side to the output side through the coupling capacitor.

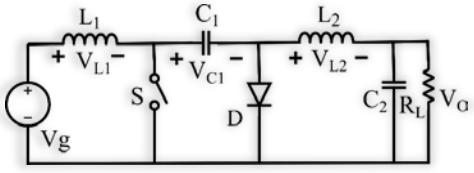


Figure 5. Basic Cuk Converter Circuit

The features of the Cuk converter are:

- Input and output current is continuous in nature.
- Low switching losses and higher efficiency.
- Have low noise generation.
- Low electromagnetic interference and

As it is a combination of buck-boost dc-dc converter, it can able to deliver output voltage both greater and less than the input voltage. The operation of Cuk converter can be divided in two modes (a) and (b) as shown in Figure 6.

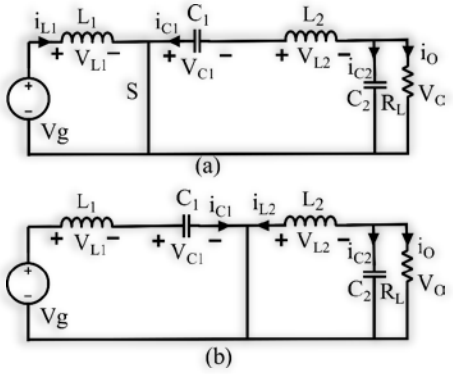


Figure 6. Operation of Cuk Converter, (a) when S is turned on. (b) When S is turned off.

Mode (a) begins when the switch S is turned on (duration is giving by $0 \le t \le DT$). At this mode current through the inductor L_1 increase as it is getting charged by the input voltage. On the other side C_1 is discharging through the output capacitor C_2 and the inductor L_2 by making diode D reverse biased. On the other mode (b) begins when switch S is turned off (duration is giving by $DT \le t \le T$). In this mode diode, D became short-circuited which help the capacitor C_1 to get charged by the supplied voltage, and the inductor L_2 transfer the energy to the load by getting discharged. So, the coupling capacitor C_1 is transferring the energy from source to load by charging and discharging. The load voltage became negative as in both the mode the current flowing through the load is opposite in direction.

Applying volt-second balance across the inductor L_1,

$$V_g DT + \left(V_g - V_{C1}\right)(1-D)T = 0 \quad (13)$$

$$V_{C1} = \frac{V_g}{(1-D)} \quad (14)$$

Applying volt-second balance across the inductor L_2

$$(V_O + V_{C1})DT + V_O(1 - D)T = 0 \quad (15)$$

$$V_O = -\frac{DV_g}{(1 - D)} \quad (16)$$

Equation (16) Represent the output of the Cuk converter. Applying the power balance the value of the current I_{L1} given as

$$I_{L1} = \frac{D^2}{(1 - D)^2}\frac{V_g}{R_L} \quad (17)$$

Voltage ripple across the capacitor C_1 is calculated as

$$\Delta V_{C1} = \frac{D^2 V_g T}{R_L C_1 (1 - D)} \quad (18)$$

≡ Canonical Switch Cell (CSC) Converter:

CSC converter is a modification of a buck-boost converter with having fewer no of devices as shown in Figure 7.

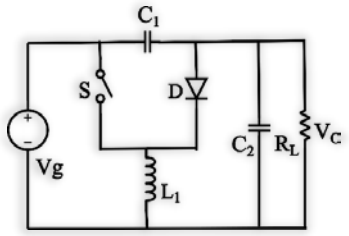


Figure 7. CSC converter circuit

The operation of the converter is divided in two different modes (a) and (b). At mode (a), as the switch S is turned on, the input inductor L_1 is getting charged from the source Vg. Simultaneously the capacitor C_1 discharges its store energy to L_1 through the switch S, as the diode became reversed bias. Mode (b) begins when the switch S became turned off. Then the diode becomes forward biased and then the input inductor L_1 discharges its energy to the output capacitor C_2. Besides that, the capacitor C_1 is also getting charged by the input voltage through diode D, as shown in Figure 8.

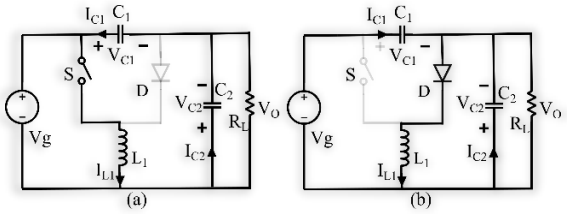


Figure 8. Operation of CSC converter.(a) When S is turned on. (b) When S is turned off.

The expression of the capacitor C_1 and C_2 are calculated as[17]

$$C_1 = \frac{V_g D}{\Delta V_{C1} R_L f_s} \quad (19)$$

$$C_2 = \frac{I_O}{2\omega_L \Delta V_O} \quad (20)$$

where R_L represent the equivalent DC load resistance, ω_L represent the angular frequency of the line voltage.

CONTROL ANALYSIS

As the SIMO converter is feed from the SPV supply, the primary purpose of the controller is to maintain a maximum power extraction from the SPV throughout the operation. Figure 9 shows the block diagram of the proposed converter control system. A feed forward controller consist of a MPPT controller and an Input Voltage Controller (IVC) has considered as total control system. After taking inputs (V_{PV} and I_{PV}) from the SPV panel, the MPPT controller develop a reference voltage V_{PV}^* with the help of PSO algorithm. Then an error signal is generated after comparing the reference signal with the SPV output voltage. There after this error signal is given as a input to the IVC and The signal D_1 is developed. An equivalent 10kHz PWM signal is generated by the PWM generator by taking the D_1 as an input.

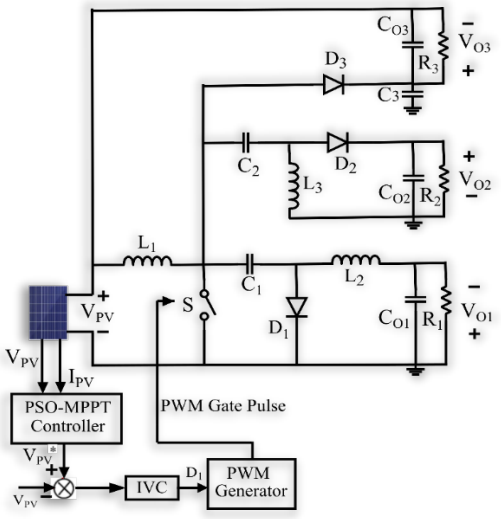
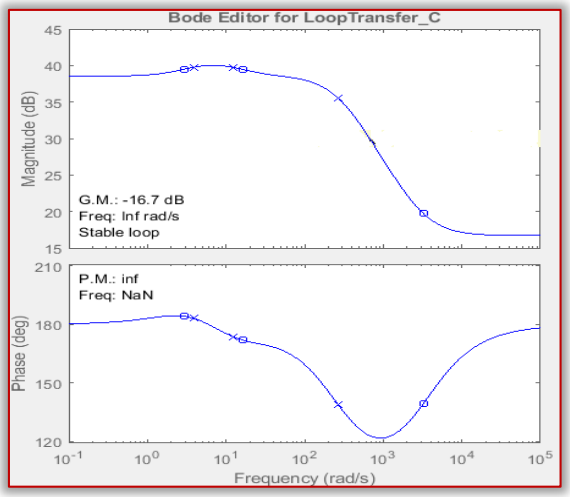


Figure 9. Overall block diagram of total system

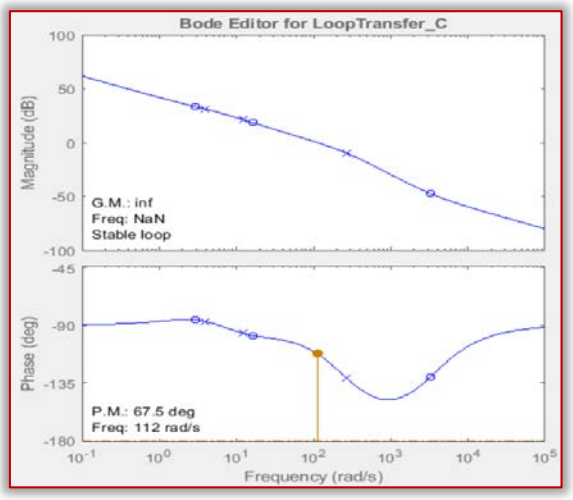
The transfer function of the proposed converter is calculated with the help of small signal modelling. After replacing the different component value the transfer function of the proposed converter is given by,

$$TF = \frac{-6.845s^3 - 2.252e^{04}s^2 - 4.33e^{05}s - 1.07e^{06}}{s^3 + 281.6s^2 + 4361s + 1.277e^{04}} \quad (21)$$

To find out the stability of the input loop magnitude and phase plot are plotted which is shown in the figure 10(a). A PID based compensator is designed to improve the stability margin and the improvement of the margins are displayed in the figure 10(b).



(a)



(b)

Figure 10. Magnitude plot and Phase plot of the Transfer function. (a) Without Compensator. (b) With Compensator

SIMULATION RESULTS

In order to verify the PSO-MPPT based SEPIC-Cuk-CSC combinational converter characteristics, a simulation is performed in MATLAB as shown in Figure 11 the details of the SPV panel and the SIMO converter component specification, which is used in this simulation is given in the table-1.

Table -1 Component specification

Name	Rating
Input Panel Power	65W
Open circuit Voltage (Voc)	22V
Voltage at MPP (Vmpp)	18.2V
Short Circuit current (Isc)	5.5A
Current at MPP (Impp)	3.55A
Inductor L1	30mH
Inductor L2 and L3	1.35mH
Capacitor C1	220µF
Capacitor C2	470µF
Resistance R1-R3	80Ω
Switching Frequency	10kHz

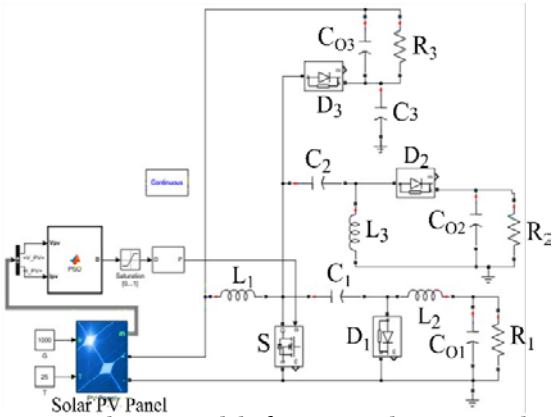


Figure 11. Simulation Model of SEPIC-Cuk-CSC Combination Converter

Fig 12(a) shows the PWM gate pulse of 10 kHz developed by the PSO-MPPT The SPV panel output voltage and the SPV panel extracted power is shown in Fig 12(b) and 12(c) respectively. A swing of SPV voltage around the Vmpp can be observed, which signifies a satisfactory execution of MPPT.

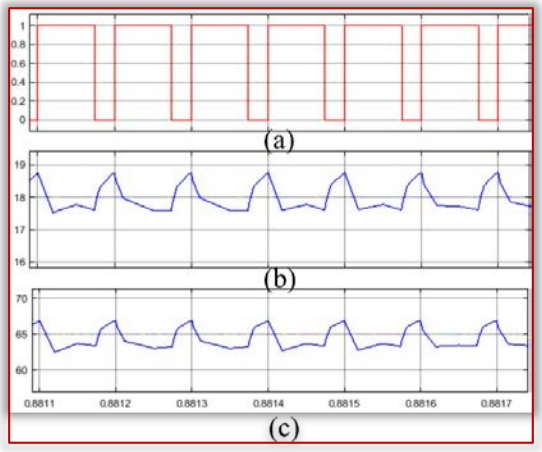


Figure 12. (a) PWM output of the PSO-MPPT controller. (b) SPV panel output voltage (c) Solar PV panel output Power

In Fig 13(b) and Fig 13(d), the charging current of the inductor L_1 and the discharging current of the inductor L_2 are clearly observed during the switch turn-on time. Besides that, the charging and the discharging of the capacitor C_1 is also shown in the Figure 13(c). Similarly, the charging and discharging of the capacitor C_2 along with the inductor L_3 of the SEPIC converter is shown in Figure 14.

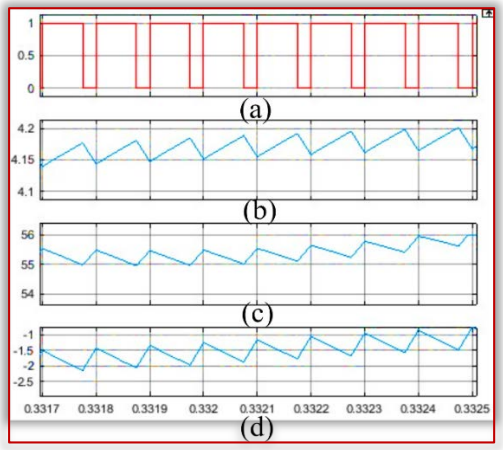


Figure 13. Cuk converter output (a) PWM Gate pulse of switch S. (b) L1 inductor current. (c)The voltage across capacitor C1. (d) L2 inductor current.

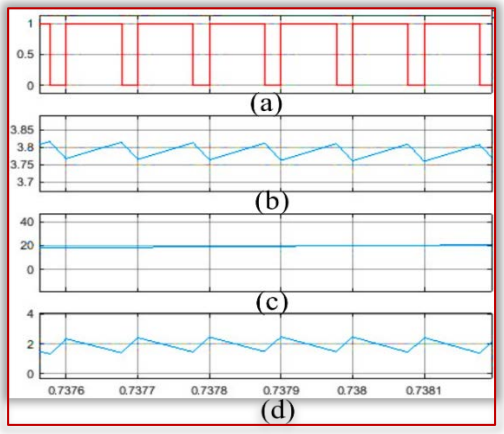


Figure 14. SEPIC converter output (a) PWM Gate pulse of switch S.(b) L1 inductor current. (c)Voltage across capacitor C2. (d) L3 inductor current.

Different characteristics of CSC converter are shown in the Figure 15. Three different voltage output with proper polarity is shown in Fig 16. Where SEPIC and Cuk converter produces almost 48V and -48V. Besides, CSC converter is developing a voltage around -18V. The currents of the three converters is shown in Figure 17. CCM operation is observed in the Cuk and CSC converter.

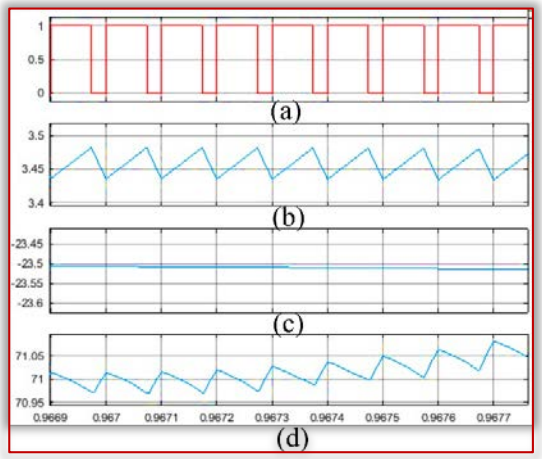


Figure 15. CSC converter output. (a) PWM Gate pulse of switch S. (b) L1 inductor current. (c)The voltage across capacitor C_{O3}. (d) The voltage across capacitor C_3.

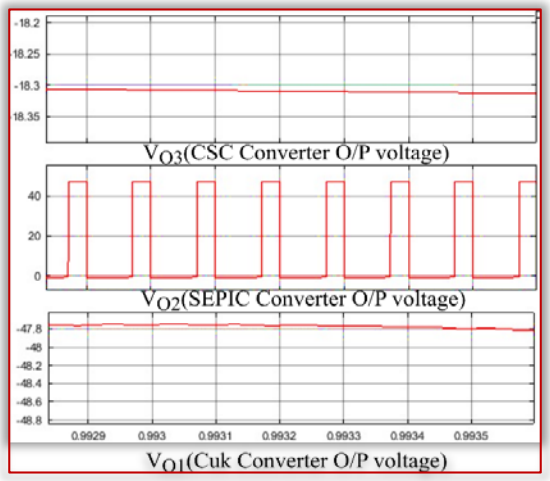


Figure 16. Multiple output voltage of SIMO converter.

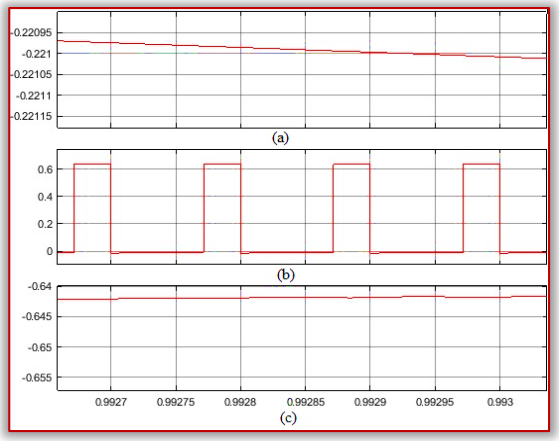


Figure 17. Multiple output current of SIMO converter. (a) CSC converter output current. (b) SEPIC converter output current. (c) Cuk converter output current.

CONCLUSION

This paper presents a design of the SEPIC-Cuk-CSC combination converter used for renewable energy applications. A PSO based MPPT method is applied to extract maximum power. According to the simulation results, it is observed that the PSO method is successfully able to track the MPP in all the conditions. Reduction of design cost and the loss are achieved by reducing the component requirement for developing multiple output voltage levels. As a future scope of this work design of SPWM based inverter can be incorporated with this system as it will helpful to transfer the power to the AC grid.

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