IMAGE: A MAP OF THE STARS OF THE ORION CONSTELLATION

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Kechen Xu

ABSTRACT

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Keywords: lactate, warburg effect, tumor, therapy.

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Keywords: lactate, warburg effect, tumor, therapy.

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I. INTRODUCTION

Lactate has long been thought to be a metabolic waste product produced by skeletal muscle during carbohydrate fermentation or anaerobic glycolysis during exercise. When cells have an excessive demand for oxygen and ATP, such as during strenuous exercise and infection, lactic acid is produced in large quantities[2,3]. Lactate is a product of glycolysis during glucose metabolism, and the glycolysis pathway is activated to produce ATP when hypoxia inhibits the tricarboxylic acid (TCA) cycle, which is presented in Figure 1.

Specifically, cells produce pyruvate through glucose metabolism, and in the absence of mitochondrial oxidation, pyruvate is directly reduced to lactic acid by a process called lactate dehydrogenase (LDH)[4]. In addition to glycolysis, glutamine catabolism is another source of lactate in cancer cells[5]. Excessive accumulation of lactate in the human body can lead to lactic acidosis[6]. In the early 1920s, Warburg found that cancer cells rapidly produce lactic acid even in the presence of oxygen, a process known as aerobic glycolysis[7]. In proliferative cells, glycolysis is so highly vigorous to ensure that intracellular and extracellular concentrations of lactate is higher than those found in cells at the resting state[8].

Notably, lactate accumulation often occurs in the tissue microenvironment in inflammatory diseases and cancers.[9]. In addition, many researchers report that the Warburg effect occurred in nontumor cells and noncancerous diseases, such as pulmonary hypertension, heart failure, atherosclerosis, pulmonary fibrosis, and polycystic kidney disease[10,11]. The main factors affecting the formation of lactate are the low oxygen environment, the concentration of glycolytic product - pyruvate, and the PH of the surrounding environment. However, most cancer cells have a relatively low oxygen microenvironment, which is conducive to the stable production and expression of hypoxia-inducing factor-1 α(HIF-1α). HIF-1α has the effect of activating glucose uptake, improving glycolysis, increasing pyruvate production, and promoting the conversion of pyruvate to lactate. A RASSF1A-HIF1α loop drives the Warburg effect in cancer and pulmonary hypertension[11]. As a glycolytic metabolite, lactate is not a waste

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product of cancer cell proliferation, but has a broad effect that plays an important role in tumor progression and metastasis[12]. To avoid intracellular acidification, cancer cells rapidly export lactate via monocarboxylate transporters (MCTs)[13]. This mechanism avoids excessive lactate concentration in the cell and ensures that aerobic glycolysis and lactate production continue while increasing lactate concentration in the extracellular tumor microenvironment (TME).

High lactate concentrations in the TME are associated with a poor prognosis[14]. In this review, we will detail the biological role of lactate in cancer cells and TME, including their influence on cancer progression, metastasis, and anti-tumor therapy.

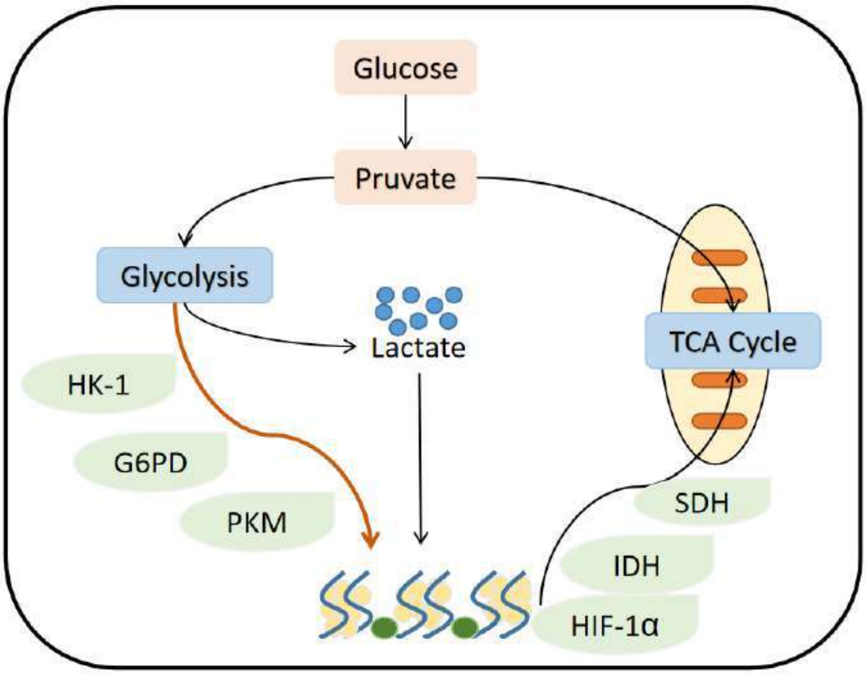

Figure 1: The Process of Lactate Metabolism

II. EFFECT ON TUMOR MICROENVIRONMENT

The tumor microenvironment (TME) is a microenvironment formed by the accelerated metabolism of tumor cells and cancer-related fibroblasts, which promotes tumor growth[15]. Lactate transport is crucial for the survival of cancer cells in the TME. Lactate, produced by the Warburg metabolism of cancer cells, is secreted into the extracellular environment, forming an active niche for tumor pathogenesis and evolution, which plays a key role in promoting cancer progression[9]. Because tumors grow faster than blood vessels form, cancer cells close to blood vessels are normoxic, while cancer cells far from blood vessels are hypoxic[12]. Specifically, hypoxic tumor cells produce lactate via lactate dehydrogenase A (LDHA), which is exported out of the cells, and normoxic tumor cells will use this lactate for ATP production with the conversion of lactate into pyruvic acid via lactate dehydrogenase B (LDHB)[12]. Monocarboxylate transporters (MCTs) belong to the SLC16 gene family, facilitating bidirectional symport of monocarboxylates and H+ across cell membranes[16]. Based on the differential regulation by hypoxia-related genes, MCT4 can modulate the release of lactate from hypoxic tumor cells and MCT1 can modulate the uptake of lactate in normoxic tumor cells[12]. Hypoxia is one of the main features of most tumors and tends to produce large amounts of lactate mediated by HIF1α[17]. HIF1α can promote invasion and resistance to chemotherapy by activating Snail and Twist, two transcription factors involved in E-cadherin modulation[18]. Numerous studies have shown that proton-coupled lactate efflux from cancer cells or stromal cells contributes to the preservation of acidic phenotypes and promote tumor progression by modulating TME, including cell invasion, survival signaling, angiogenesis, metastasis development, and evasion of immune surveillance[19]. Cell surface lactate receptor GPR81 is crucial for cancer cell survival, presenting in the colon, breast, hepatocellular, lung, gland, cervical, salivary, and pancreatic carcinoma cell lines[20]. Studies have shown that lactic acid secreted by tumor cells activates GPR81 on tumor cells, resulting in a carcinogenic phenotype[20].

Extracellular lactate levels can affect cells and modulate their function in TME, including cancer cells, T cells, NK cells, macrophages, and dendritic cells, which can trigger intracellular signaling that fine-tunes cell behavior[21–25]. Because extracellular acidosis can suppress T-cell-mediated immunity, neutralizing tumor acidity can improve antitumor response to immunotherapy[9]. Acidosis will affect the potential function of T cells. In TME, low pH reduces the expression of iNOS, CCL2, and IL-6 in M1 macrophages, but increases the expression of M2 macrophage markers, and also inhibits the anti-tumor activity of NK cells[26,27]. Lactate high levels in TME also reduce lactate efflux from T cells, resulting in their decreased cytokine production and cytotoxic activity[28].

III. EFFECT ON TUMOR ANGIOGENESIS

Lactate can promote angiogenesis in TME, like a trauma-related microenvironment, stimulating endothelial cell activation and angiogenesis via HIF-independent and HIF-dependent pathways[8]. Some evidence shows that the proangiogenic factor, vascular endothelial growth factor (VEGF), can be induced via both HIF-dependent and HIF-independent pathways[29]. In the HIF-independent pathway, lactate is transferred into cells through MCT1, oxidized to pyruvate to produce NADH that can activate ROS production, which can stimulate angiogenesis[30]. Moreover, lactate can facilitate angiogenesis by directly binding the NDRG3, which activates Raf-ERK signaling to mediate lactate-triggered hypoxia responses[31]. With the low oxygen tension and high lactate concentrations, NDRG3 will bind c-Raf to activate RAF-ERK signaling and promote angiogenesis[31]. The mechanism of the HIF-dependent pathway is that the relatively constant level of lactic acid can maintain the constant level of HIF-1α under normal oxygen conditions. Aberrant activation of the HIF pathway causes overexpression of angiogenic genes, like VEGF[32]. HIF-1α is a vital regulator of metabolic reprogramming in hypoxic cancer cells[33]. As the main oxygen sensors in cells, proline hydroxylases (PHDs) can hydroxylate HIF-1α at specific proline residues to promote the subsequent degradation of HIF-1α by the UPS under normoxic conditions[8]. However, PHD is devitalized under hypoxic conditions. This inactivation of PHD suppresses the proteasomal degradation of HIF-1α, making HIF-1α migrate to the nucleus and facilitates the transcription of some tumor-promoting genes[34]. Pyruvate, which is converted by tumor cells through lactic acid, competes directly with α-KG, inhibiting PHD activity and thus stabilizing HIF-1α levels[34]. Therefore, stable HIF-1α levels can ensure high lactate concentrations in TME, thus guaranteeing transcriptional activation of tumor-promoting genes in all tumor cells[8].

VI. EFFECT ON TUMOR IMMUNITY

In some previous studies, lactate in the TME inhibits NK cell function and prevents the activation of NFAT in both T cells and NK cells, resulting in diminished IFNγ production[22,35]. The decrease in NK cell function and IFNγ production will affect the anti-tumor effect. In the TME, the effects of lactic acid on cancer and immune cells are complex and difficult to decipher, which is further confused by acidic protons (a byproduct of glycolysis). Interestingly, there is the latest finding that has upended our conventional understanding of lactate, which can increase stemness of CD8+ T cells and augments anti-tumor immunity[1]. This finding reveals metabolic reprogramming of immune function and distinguishes the role of lactic acid and tumor acidity in anti-tumor immunity. The experimental group injected lactate subcutaneously into colon cancer mice, and the control group injected glucose solution into tumor-bearing mice, and it was found that lactate treatment significantly inhibited tumor growth[1]. Further single-cell RNA sequencing analysis showed that lactic acid treatment increased the number of infiltrated CD8+ T cells in the tumor[1]. When the same experiment was performed in mice genetically engineered to lack CD8+ T cells, the tumor inhibitory effect of lactic acid was blocked[1]. The researchers also found that lactic acid alone did not completely clear tumors; But when histone deacetylase (HDAC, a commonly used immune checkpoint inhibitor) was added, the tumors disappeared completely in about half of the mice[1].

In addition, lactic acid significantly improved the efficacy of anti-cancer vaccines and increased the anti-cancer response of CD8+ T cells cultured in tumor-bearing mice[1].

V. CLINICAL SIGNIFICANCE AND THERAPEUTIC TARGETS

Previously, lactic acid is considered an indicator of high malignancy and poor prognosis in several cancers. On the one hand, lactic acid inhibits immune cell action in TME. On the other hand, lactic acid can be directly absorbed and metabolized by tumor cells to promote the TCA cycle. The immunoprotective effect of lactic acid has not been fully appreciated before because the immunosuppressive effect of tumor acidity predominates. New research reveals the special immunoprotective role of lactic acid in anti-tumor immunity, thus suggesting that lactic acid could be used to supplement existing cancer immunotherapies[1]. Lactate is widely used clinically as sodium lactate Ringer's or Hartmann's solution, and there is sufficient evidence that it can be safely used in fluid resuscitation and to reduce metabolic acidosis.

Current Ringer's fluid or modified solutions with increased lactate concentrations can protect CD8+ T cell function during immunotherapy in cancer patients. The addition of lactic acid to the expansion of isolated T cells may be beneficial for chimeric antigen receptor T cell (CAR-T) therapy.

Footnotes

Availability of data and materials

Not applicable.

Authors' contributions

KCX contributed to the manuscript writing and revision.

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Competing interests statement

The authors declare no conflict of interest.

Patient consent for publication

Not required.

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Analysis of the Electromagnetic Spectrum of Mobile Operator in the 850-1900 MHz Frequency Range

Dr. Millard Escalona

Universidad Bicentenaria

SUMMARY

The present investigation was based on analyzing the signal generated by the electromagnetic spectrum display equipment SAG4400L-NWT4000. Taking into account an operating range of 850-1900 MHz of a mobile operator. With the use of this device, it was possible to compare the theoretical vs. experimental postulates obtained through the tests carried out in this study.

Keywords: frequencies, electromagnetic spectrum, bandwidth, signal, magnetic field, powers.

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Author: Universidad Bicentenaria de Aragua.

I. INTRODUCTION

Radio communication is defined as telecommunication by means of radio waves, which are electromagnetic waves propagating without artificial guidance at frequencies below 3,000 GHz. Technically radiation is an outgoing flow of electromagnetic energy from any source, while emission is the radiation by a transmitting station [1].

The birth of GSM (Groupe Special Mobile) technology took place in Europe in 1982, within the framework of the European Conference of Postal and Telecommunications Administrations, with the aim of bringing together the digital and mobile communication systems existing at the time. [1]. The possibility of design allowed several operators to share the spectrum, so that users can connect to their preferred network. Consequently, signals can be seen as a function of frequency, through a spectrum analyzer. Using the SAG4400L-NWT4000- 35MHz-4.4GHz device, it is possible to determine the electromagnetic spectrum traffic in the 850-1900MHz frequency of an operator. In addition, the formulas involving the analysis of electromagnetic waves are presented in a theoretical way.

II. SAG4400L SPECTRUM ANALYZER

The SAG4400L spectrum analyzer can measure the frequency bands from 35MHz to 4.4GHz. The functions of the device are described below. [2]

2.1 Specifications

Table 1: Sag4400l Spectrum Analyzer Technical Specifications

Input-output frequency range	35 MHz – 4,4 GHz
Input-output frequency measurement	1kHz
Maximum Input Power	+8dBm
Noise Level	-70 dBm
Intermediate Frequency Bandwidth (IF)	250 kHz*2
Measurements	120*65*25
Source	+5v / 0,35 A

2.2 SAG4400L-NWT4000 Device Structure

The SAG4400L electronic device consists of two plugs. An input (IN) for the signals to be analyzed. In turn, an output (OUT), which generates the spectra corresponding to certain values.

Fig. 1: External View of SAG 4400L-NWT4000 Device

The interior is composed of two sections: The signal generator and spectrum analyzer. It means that both parts are connected, through a Serial to USB converter, allowing the installation of the corresponding software for simulation.

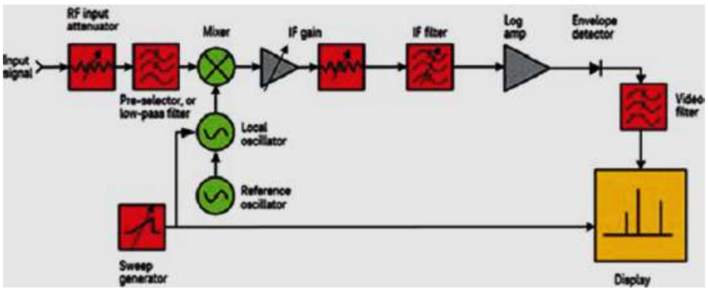

Fig. 2: Block Diagram of a Superheterodyne Spectrum Analyzer

In general, the blocks that make up the SAG4400L- NWT4000 Spectrum Analyzer are analyzed. In the first instance, the signal capture uses a connector on the input signal. In turn, it enters through a high-pass filter block to avoid the high frequencies of 4.4GHz. Next, there is the schematic of a multiplexer that combines the incoming signal with one emitted from the ADF4350 generator, at a frequency of 1 GHz. [3]. In the next block, there is a low-pass filter to eliminate frequencies lower than those set by the software. On the other hand, the diagram of a logarithmic signal amplifier is shown. Finally, the logarithmic signal arrives to an ATMEGA microprocessor that is in charge of capturing the samples and sending them to the software, by means of the RS-232 to USB converter (FT232).

2.3 WinNWT4 Software Configuration

The WinNWT4 software allows to visualize spectra, generate signals, by means of an interactive configuration panel. Consequently, the availability of measuring the power of a signal is feasible.

When installing the program, the USB port of the computer must be configured to recognize the SAG440L-NWT4000 device. If the installation fails, the drivers distributed by the device manufacturer must be installed. It is essential to indicate the serial port that the computer has in order to be compatible with the program.

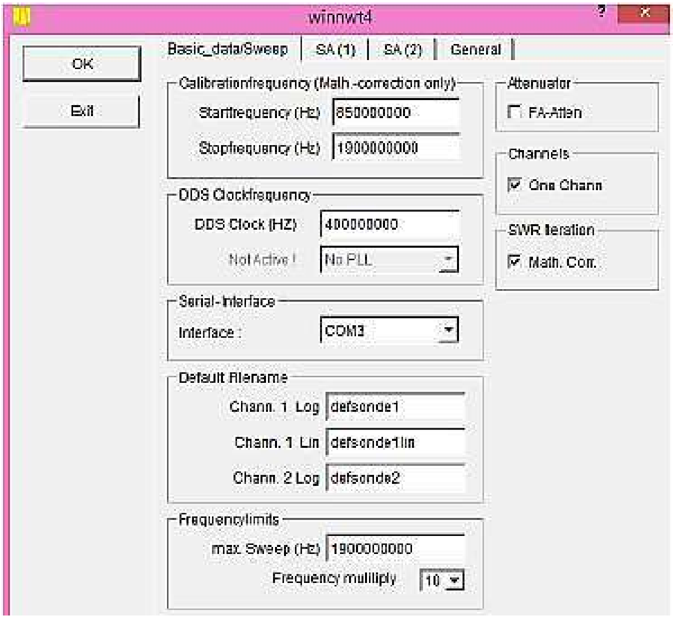

Fig. 3: WinNWT4 configuration window

2.4 SAG4400L Device Configuration

Once the port number is identified, the program is run to configure the spectrum analyzer function. In the main window of the software, go to the (Setting's) tab and choose the (Options) display; a tab is generated according to Fig.4. Then select the Serial-USB port number in the (Serial-interface) option, this port must match the found device manager port. Now, set the frequency ranges for the band to be analyzed. To do this, go to the option (Calibration Frequency), where the start frequency of the band is set to (Start frequency) and the end frequency to (Stop frequency). The item (DDS Clock frequency) is the frequency at which the device will be sampled. The recommendation is to set it to 1 GHz. For the (Frequency limits) tab, enter the Maximum Sweep Frequency and modify the Adjustment Rate for the signal. By default, the real frequency is assumed as a multiplication factor of the display frequency * 10.

Now, enter the main program window and in the (Mode) block, select (Sweep mode), only to analyze spectra. Finally, the delay time (Interrupt's) is set, which is used to assume the delay time in the capture of the measurements, through the power of each sample. The recommendation is to leave the value fixed at: 0 μs.

III. CONCEPTOS FUNDAMENTALES

3.1 Magnetic Field

A magnetic field is a region of space where magnetic forces exist, forces that attract or repel metals. It is an invisible field that exerts a magnetic force on substances that are sensitive to magnetism. [4] [5].

$$B\left(\frac{A}{m}\right) = \sqrt{\frac{2 \cdot \mu_0 \cdot S}{c}} \qquad (1)$$

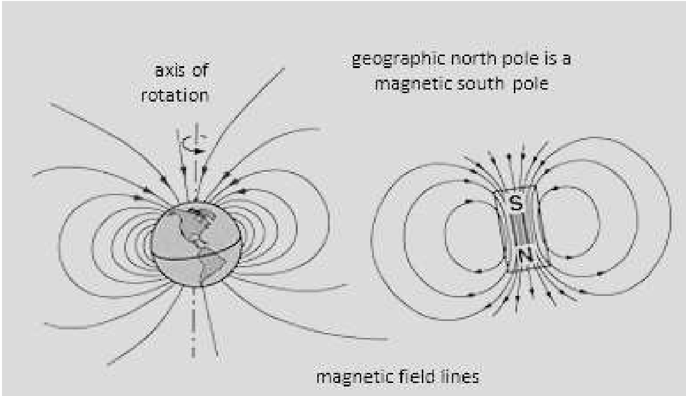

Fig. 4: Interpretation of the Magnetic Field

Magnetic field lines are a way of representing this magnetic field. Magnetic fields can be generated by magnets or by electric currents. The lines tell us how strong the field is and how far its action reaches. [6]

3.2 Electric Field

The electric field is the region of space in which the electric force interacts, or a physical field that is represented by a model describing the interaction between bodies and systems with properties of an electrical nature.

$$F = qE \tag{2}$$

3.3 Electric Field Strength

A The electric field strength (E) at a point is a vector quantity representing the electric force (F) acting per unit of positive witness charge, which located at that point is mathematically defined as:

$$E\left(\frac{V}{m}\right) = \sqrt{2 \cdot \mu_0 \cdot c \cdot S} \tag{3}$$

3.4 Power

Electrical power is a parameter that indicates the amount of electrical energy transferred from a generating source to a consuming element per unit of time.

3.5 Bandwidth

In Internet connections, bandwidth is the amount of information or data that can be sent over a network connection in a period of time. [6]

3.6 Maxwell's Equations

These equations are considered the basis of all electrical and magnetic phenomena

$\oint \mathbf{E}.d\mathbf{A} = \frac{Q}{\varepsilon_0}$	*Gauss Law*
$\oint \mathbf{B}.d\mathbf{A} = 0$	*Gauss Law of Magnetism*
$\oint \mathbf{E}.d\mathbf{s} = -\frac{d\Phi_B}{dt}$	*Faraday Law*
$\oint \mathbf{B}.d\mathbf{s} = \mu_0 I + \varepsilon_0 \mu_0 \frac{d\Phi_E}{dt}$	*Ampere-Maxwell Law*

Fig. 5: Maxwell's Equations

3.7 Electromagnetic Waves

An electromagnetic wave is composed of an electric field and a magnetic field as a function of time, electromagnetic waves carry power and this can be determined through the Poityng Vector which determines the power flux density. The formula is defined as follows [7]

$$S\left(\frac{W}{m^2}\right) = \frac{E^2}{2\cdot\mu_0\cdot c} \tag{4}$$

3.8 Sinusoidal Electromagnetic Waves

They are waves that travel at the speed of light, and the magnetic and electric fields are perpendicular to each other; these waves obey the principle of superposition.

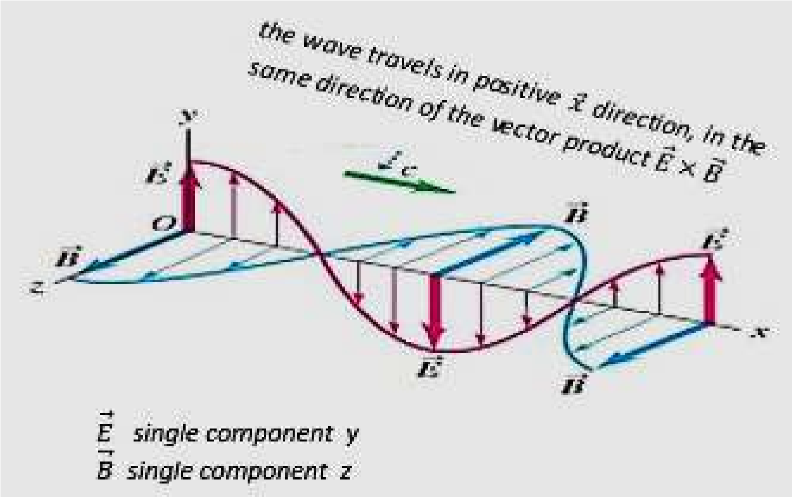

Fig. 6: Sinusoidal Electromagnetic Wave Polarized Through the X-Axis

3.9 Wavelength

When an electromagnetic wave is analyzed in a small part of vision can be made relation of this as if it were a plane wave. The frequency f, the wavelength λ and the speed of propagation c have a close relationship therefore:

$$\lambda = \frac{c}{f} \tag{5}$$

IV. ANALYSIS PARAMETERS (CALCULATIONS)

According to the regulations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP). It establishes parameters for the Electric Field Intensity and Magnetic Field Intensity allowed in a population profile. These values allow the development of Theoretical Calculations.[8]

For a frequency range between 400-2000MHz the equations for Electric Field Strength, Magnetic Field Strength and Plane Wave Power Density (Poityng) are, given in (V/m), (A/m), (W/m^2):

$$E = 1,374\cdot f_p^{1/2} \tag{6}$$

$$B = 0,0037\cdot f_p^{1/2} \tag{7}$$

$$S = \frac{f_p}{200} \tag{8}$$

4.1 Sample 1 of 850-950 MHz

Data:

f_1: 850 MHz

f_2: 950 MHz

$\mu_o = 4\pi\times10^{-7}\ H/m$ (vacuum permeability)

$\varepsilon_o = 4\pi\times10^{-12}\ F/m$ (medium permittivity)

$c = 3\times10^{-8} m/s$ (speed of light)

a) *Average Frequency*

$$f_p = \frac{f_1+f_2}{2} \tag{9}$$

$$f_p = \frac{f_1+f_2}{2} = \frac{(850+950)}{2} = 900\ MHz$$

b) *Wavelength*

$$\lambda = \frac{c}{f} = \frac{3\times10^{-8} m/s}{900\times10^{6} Hz} = 33,3310^{-18} m = 33,33\ am$$

c) *Electric Field Strength*

$$E = 1,374\cdot\left(900\times10^{6}\right)^{\frac{1}{2}} = 41,25kV/m$$

d) *Magnetic Field Strength*

$$E = 0,037\cdot\left(900\times10^{6}\right)^{\frac{1}{2}} = 11,11\ kA/m$$

e) *Power Density*

$$S = \frac{900\times10^{6}}{200} = 4,6\ M\ (W/m^{2})$$

f) *dBm power*

$$P = 10\ log_{10}(\frac{E}{1mW})$$

$$P = 10\left(\frac{41,25\times10^{3}}{1mW}\right) =-\ 76,15\ dBm$$

The calculations are carried out in the same way for each of the frequencies involved in the analysis.

V. MOBILE OPERATOR COVERAGE IN THE GEOGRAPHIC ZONE

The operator has GSM technology; 2G-3G network for frequencies between 850-1900 MHz and for 4LTE technology 4G network frequencies between 1700-2100 MH.

Table 2: Frequency Band -Mobile Operator

Technology	Frequency	Network	Service
GSM	850 /1900 MHz	2G-3G	Voice and Data
4LTE band	1700/ 2100 MHz	4G	Data

Fig. 7: Operator Coverage Area

5.1 2G and 3G network

These are networks that can be connected to a cellular phone when a user is in remote locations, such as rural or mountainous areas. With 2G networks the speed is lower and generally voice has preference over data, and these two services cannot work at the same time.

The main difference between 3G and 2G networks is that 3G offers faster browsing speeds; moreover, with 3G networks on a phone or tablet, voice and data services can operate at the same time.

5.2 4G Network

They represent the fourth generation of mobile telephony technologies. These networks represent the next step up from the current 3G and are available to customers. With them, the data network improves in quality and speed, allowing speeds of up to 75 Mbps downstream (download) and 25 Mbps upstream.

VI. RADIO FREQUENCY SPECTRUM ANALYSIS

Spectrum analyzer allows plotting the amplitudes or levels of the frequencies of a specific signal. The 35MHz-4.4GHz SAG4400L-NTW4000 device has been used. This device will be used to determine the electromagnetic spectrum traffic in the 850-1900MHz frequency of the operator in the area determined for measurements. In turn, 6 samples have been taken in the above-described range for their respective comparison.

Table 3: Device Configuration Parameters Sag4400l-Nwt4000, Frequency Range 890-1900 Mhz

Starfrecuency (Hz)	850000000 Hz	Initial Frequency
Stop Frequency (Hz)	1900000000 Hz	Frequency Final
DDSclock (Hz)	40000000 MHz	Sampling Synchronization
Frequency limits (Hz)	1900000000 Hz	Spectrum Sweep Frequency
Frequency multiple	10	Multiplication Factor for Plotting the Signal
Average Power (dBm)	-74,425	

A range in dBm y-axis has been selected for the respective analysis.

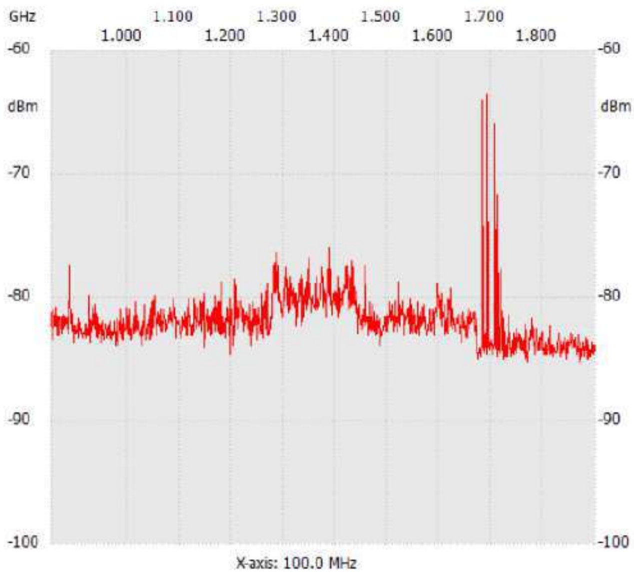

Fig. 8: Frequency Spectrum Plot of the Operator's Band. With the SAG4400L-NWT4000 Spectrum Analyzer Equipment Between 850-1900 MHz

Interpreting the graph in Fig. 8. The decibels (dBm) of incidence of the weighting is observed in the 800-1500 MHz band, note that the maximum peaks of before and after due to the data traffic located approximately in the 1700MHz.

Then, 6 samples have been selected, divided between the 850-1450 MHz range

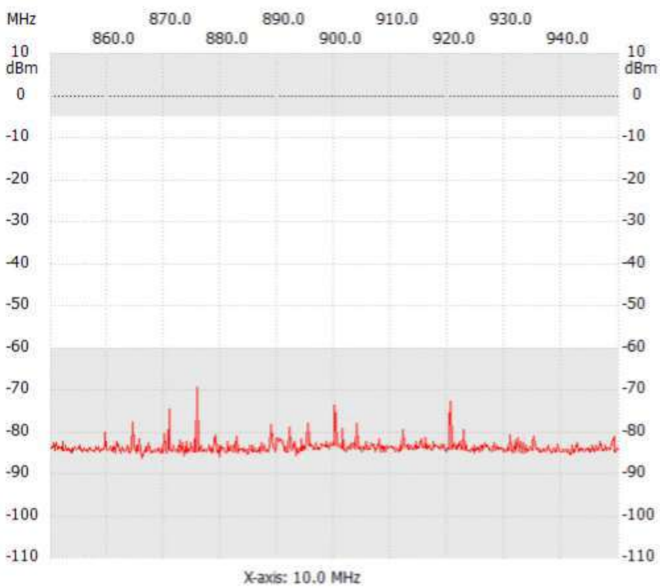

Fig. 9: Sample 1: Plot of the Frequency Spectrum of the Band. With the Spectrum Analyzer SAG4400L-NWT4000 Between 850-950MHz

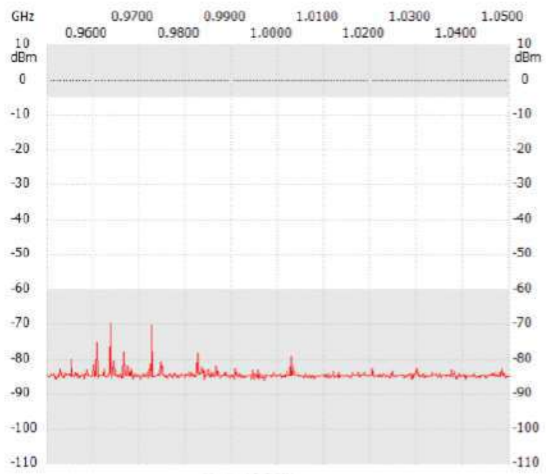

Fig. 10: Sample 2: Plot of the Frequency Spectrum of the 950-1050 MHz Band with the SAG4400L-NWT4000 Spectrum Analyzer

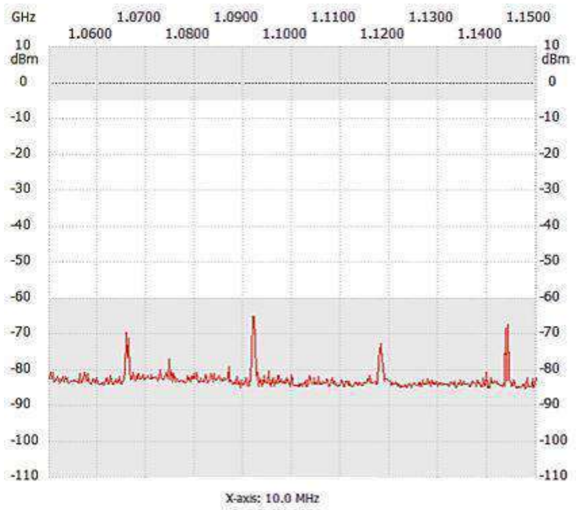

Fig. 11. Sample 3: Plot of the Frequency Spectrum of the Band. With the Spectrum Analyzer SAG4400L-NWT4000 Between 1050-1150 MHZ

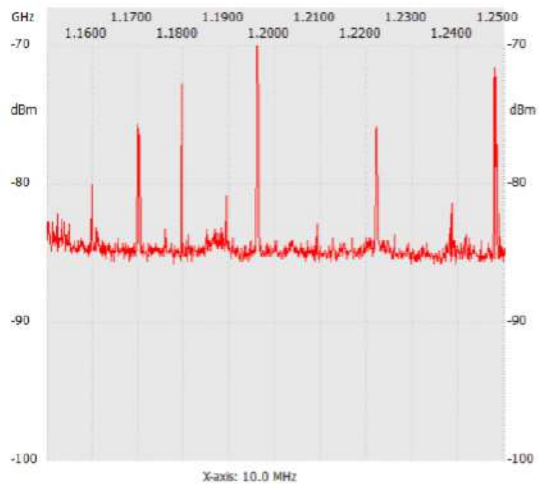

Fig. 12: Sample 4: Plot of the Frequency Spectrum of the Band. With the Spectrum Analyzer SAG4400L-NWT4000 Between 1150-1250 MHz

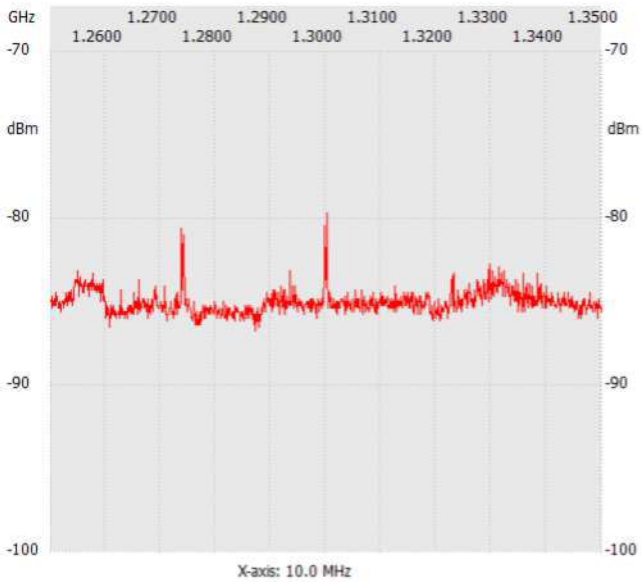

Fig. 13. Sample 5: Plot of the Frequency Spectrum of the Band. With the SAG4400L-NWT4000 Spectrum Analyzer Equipment Between 1250- 1350MHz

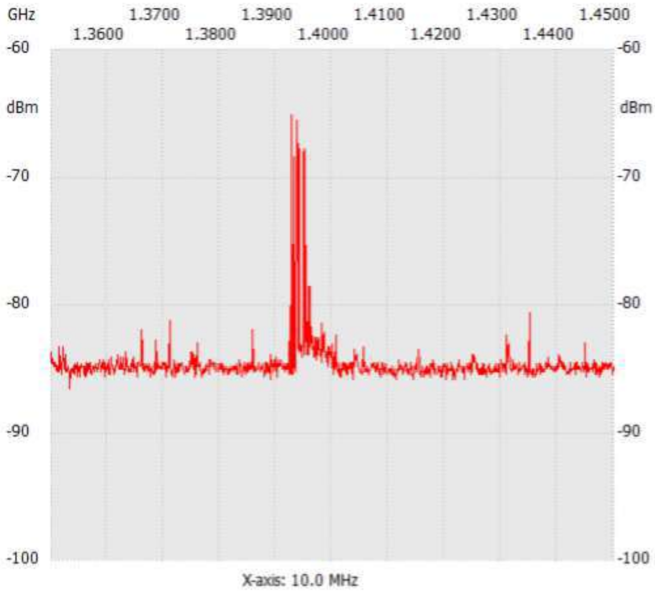

Fig. 14. Sample 6: Plot of the Frequency Spectrum of the Band. With the Spectrum Analyzer SAG4400L-NWT4000 Between 1350-1450 MHz

Table 4: Experimental Comparative Power Analysis of the Sag4400l- Nwt4000 Operator Frequencies, Frequency Range 890-1550 Mhz

Rango de Frecuencias (MHz)	Potencia Máxima (dBm)	Potencia Mínima (dBm)	Potencia Promedio (dBm)	Potencia Calculada (dBm)
850 - 950	-69,36	-86,18	-77,77	-76,15
950 - 1050	-69,65	-85,99	-77,82	-76,37
1050 - 1150	-65,15	-85,61	-75,38	-76,58
1150 - 1250	-69,65	-86,37	-78,01	-78,77
1250 - 1350	-79,11	-85,99	-82,55	-81,95
1350 - 1450	-65,15	-86,57	-75,86	-77.11

VII. CONCLUSIONS

The SAG4400L device generates Radio Frequency waves, these were validated and the data obtained were compared with the theoretical values for such frequencies, by simulating the mathematical models used by the laws of electromagnetism. On the other hand, it is evident that the transmission power in the frequency range between 850-1950 MHz is within the levels established by the International Telecommunication Union (ITU) Standards. Consequently, the theoretical and experimental power values, measured in dBm, are similar. Finally, by generating more data traffic in the different frequency categories analyzed, more peaks, disturbances or disturbances (noise) are generated when visualizing the graph of such measurements.

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Date Palm Byproducts: A Sustainable Material Base for the Future Bioeconomy

Prof. Dr. Hamed EL-Mously

INTRODUCTION

The date palm byproducts result from the annual pruning of date palms (e.g. leaves or fronds, petioles, empty fruit bunches, spathes, leaf sheaths fibers), processes of renewal of date palm plantations (date palm trunks), as well as sorting and manufacture of dates (date kernels and date wastes). Unfortunately these byproducts are most dominantly treated as waste, being either open-field burnt resulting in tremendous environmental pollution, or dumped in landfills.

This results into heavy environmental pollution and inflicts huge economic losses. Meanwhile, these date palm byproducts can be considered as a sustainable feedstock of renewable materials that can serve as a sustainable material base for a wide spectrum of industries to satisfy human needs and as a springboard for circular bioeconomy.

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This results into heavy environmental pollution and inflicts huge economic losses. Meanwhile, these date palm byproducts can be considered as a sustainable feedstock of renewable materials that can serve as a sustainable material base for a wide spectrum of industries to satisfy human needs and as a springboard for circular bioeconomy.

II. CULTURAL AND ECOLOGICAL SIGNIFICANCE OF THE DATE PALM

The date palm has been assimilated as a cultural/spiritual theme in both the Jewish and Christian traditions that have been evolved in the Middle-Eastern region. In addition the date palm has been mentioned- more than any other tree- for 23 times in Quran. The date palm's huge benefits and wide spectrum of uses of its components has been highlighted in Prophet Mohammed's teachings by comparing the date palm with the Muslim. Besides, the date palm components have been intensively used in Medinah (the first Moslem city): as building materials (date palm trunks and midribs in roofing and walling), as well as in household (stuffing of leather pillows with leaf sheaths fibers and weaving carpets from date palm leaflets) and reliance on dates as an essential component of diet. From the ecological point of view the date palm represents a keystone species and the tree of life creating in arid and semi-arid regions a microclimate that offsets the effects of drought, preserves high soil moisture with low salinity and thus creates a biodiversity hotspot that can shelter a wide range of plant and animal species in hot desert conditions.

III. THE DATE PALM BYPRODUCTS: DESCRIPTION, HISTORY OF UTILIZATION AND ASSOCIATED TECHNOLOGICAL HERITAGE

The date palm abundantly exists in North Africa, The Arab Peninsula and Iran. The first emergence of date palm dates back to 4000 B.C in Mesopotamia. This long history, along with the high renewability rate, has led to the accumulation of a rich technical heritage associated with the utilization of all the secondary date palm products, including whole leaves (midribs, leaflets), petioles, spadix stems, leaf sheaths fibers, date kernels and trunks. Midribs have been used in roofing, fencing, furniture making, and manufacturing crates and coops.

Leaflets have been used in making mats, baskets and bags. Leaf sheaths fibers have been used in making ropes, nets, bags, brooms and fly whiskers. Spadix stems have been used in making brooms and household sieves. In addition, fibers obtained from spadix stems have been used for tying agricultural crops. The palm trunk has been used as windows lintels, beams and columns in construction. Moreover, trunks have been used as a wood substitute in furniture making

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IV. FUTURE APPLICATIONS OF DATE PALM BYPRODUCTS IN CIRCULAR BIOECONOMY

4.1 Date Palm Byproducts in Enzymes, Food, Beverage, Pharmaceuticals, Cosmetics and Natural Wax

Peroxidase- an important enzyme of a high added value- has been successfully extracted from date palm leaflets, usually treated as waste! Seeds from waste dates have been used as a source for functional ingredient in food systems enjoying a high economic feasibility. Date palm leaflets and midribs have been successfully used as a substrate for microbial protein production.

Carotenoids- natural colors of a very high commercial value- have been extracted from date wastes. Date palm leaflets have been used as a substrate for growth of pleurotus fungi. Bakers' yeast and citric acid have been extracted from date wastes. Glucose and citric acid have been extracted from date palm fronds, petioles and leaf sheaths. Lactic acid, successfully produced from date palm sap, has revealed the existence of a diversity of microflora including yeasts, coliforms and lactic acid bacteria, which can be used as a starter culture for the production of fermented beverage. Insoluble fibers were extracted from waste dates being a good dietary source rich in mineral contents and can be used as an excellent food ingredient. Date palm kernel extract was found to exhibit antiaging effect suggesting its use in antiaging skin care products. Seeds oil extracted from date palm seeds was successfully used in cream, liquid shampoo and bar shaving soap. Natural wax was successfully extracted from date palm leaflets to be used in cosmetics and health care products.

4.2 Date palm Byproducts in Fibers, Textiles and Composites

The date palm is a very rich source of cellulosic fibers. Fibers can be extracted from different parts of the date palm including midribs, spadix stems, leaflets, leaf sheaths and even the trunk at the end of the palm life. The extracted date fibers have promising properties when compared to other natural fibers like flax, hemp and sisal. There is a great potential of the date palm fibers as a newcomer to the natural fibers' library.

4.3 Date palm Byproducts For Cellulose and Cellulose Derivatives Production

Nanofibrillated cellulose and cellulose nanocrystals were extracted from date palm midribs and successfully used in the reinforcement of nanocomposites (latex). Microfibrillated cellulose and oxidized microfibrillated cellulose were extracted from date palm midribs and successfully used for the improvement of paper sheet properties. Enzymatic treatment was used for the isolation of microfibrillated cellulose from date palm fruit stalks dominantly treated as waste. Microcrystalline cellulose having wide applications in pharmaceutical, food and cosmetics applications has been isolated from date palm stalks with a yield of 35.4%. Its high crystallinity (79.4%) endowing it with high rigidity opens a great potentiality for its use as a reinforcing material in nanocomposites.

Oxidized nanocellulose has been successfully extracted from date palm leaf sheath fibers and used as a packaging additive for better packaging properties. Cellulose whiskers were successfully extracted from date palm midribs and leaflets and characterized. Only cellulose whiskers extracted from midribs were used in the reinforcement of nanocomposites (rubber) due to their higher geometrical characteristics (higher aspect ratio). Microfibrillated cellulose was successfully extracted from date palm fruit stalks using enzymatic treatment. This proves the economic and developmental potentiality of realizing such a high added value product from date palm fruit stalks dominantly treated as waste.

4.4 Date palm Byproducts In Timber and Wood Substitutes

The research(Wang, D., & Sun, X. S. (2002). Low density particleboard from wheat straw and corn pith. Industrial Crops and Products, 15(1), 43–50. https://doi.org/10.1016/S0926-6690(01)00094-

2) results proved the potentiality of manufacture of palm midrib blocks enjoying mechanical properties (e.g. modulus of rupture, modulus of elasticity, maximum compressive strength, nail pull-through test results and hardness) comparable with those for spruce and beech woods.

The rationale behind the research topic (Hamed El-Mously., *rediscovering date palm by-products: an opportunity for sustainable development, keynote lecture, the first international conference for palm by-products,* 2018.): organic products from date palm midribs and leaflets is to test the technical and developmental feasibility of reliance on the traditional artisans and the tools they possess in the manufacture of new designs of products and thus opening new markets locally, nationally and worldwide. Besides, this suggested approach means beginning the first cycle of production from the top of cascade of utilization of palm midribs and leaflets thus giving wide chances for subsequent life cycles. It is expected that the green products markets and ecotourism will be most interested in organic products, made from date palm midribs and leaflets. The following organic products from palm midribs and leaflets have been designed and manufactured:

- Room divider - Armchair
- Library - Chair
- Partition - Basket
- Photo frame - Window unit
- Sweeper stick

The rationale behind the research topic(Hamed *el-mously., rediscovering date palm by-products: an opportunity for sustainable development, keynote lecture, the first international conference for palm by-products, 2018.):* Mashrabiah products from date palm midribs, is that Mashrabiah(Arabesque) is an important feature of Islamic house architecture in Egypt and the whole Arab world. Mashrabiah (Arabesque) in houses helps in preserving the privacy of house dwellers and in ameliorating the harshness of sun rays especially in summer, while introducing light and allowing the house residents to have a look from windows on the outside world without being exposed to the public! The drastic increase in prices of imported beach wood has led to the shrinkage of demand on Mashrabiah (Arabesque) products. Thus the discovery of the date palm midrib enjoying physical and mechanical properties comparable with those for imported woods (spruce, pine and beech) opened before us a new realm of development: going to remote villages where the date palm plantations are extensive, teaching the poor there (especially women) the crafts of turning palm midrib pieces on lathes and thus reviving the traditional skills of Mashrabiah (Arabesque) manufacture. Thus, a village (Gedeidah village) in the New valley governorate in Egypt was chosen as a site for the project. A new multi-purpose lathe was specially designed and manufactured to suit work in houses of beneficiaries. A training center has been established to secure palm midrib pieces for the beneficiaries. Thus Mashrabiah (Arabesque) products were manufactured by beneficiaries from date palm midribs with high quality.

How modern pieces of furniture were manufactured from date palm midribs? Four designers joined our team of rediscovery of the date palm byproducts. They put their bet on the uniqueness of the date palm midrib and its specific beauty features as compared with imported wood species. Their effors has led to the design and manufacture (in village conditions) of new pieces of furniture to satisfy contemporary needs of high and high-middle class citizens in Egypt. Thus a new market for products from date palm midribs has been opened to satisfy local contemporary needs in Egypt.

Within the framework of the research (Hamed El-Mously., *rediscovering date palm by-products: an opportunity for sustainable development, keynote lecture, the first international conference for palm by-products,* 2018.) on flooring and parquet products from date palm midribs different chemical treatments have been applied on samples of date palm midribs with the objective of improvement of dimensional stability properties, static bending properties and obrasion resistance to be used in flooring and parquet products. Thus selective treatments could be chosen for the improvement of physical and mechanical properties of date palm midribs to be used in flooring and parquet products manufacture.

A research (Shafie, M., & Zarea-Hosseinabadi, H. (2019). Eco friendly laminated strand lumber from date palm rachis: Analysis of mechanical properties by Taguchi design of experiment. Drvna Industrija, 70(4), 359–367.)has been conducted on ecofriendly laminated strand lumber from date palm midribs. The research results have proven that the laminated strand lumber manufactured from date palm midribs enjoys similar or superior strength properties compared to solid lumber and engineered products from wood or other lignocellulosic materials for building sector.

The rationale behind the research (Hamed El-Mously., *rediscovering date palm by-products:an opportunity for sustainable development, keynote lecture, the first international conference for palm by-products,* 2018.)) on blockboards with core layer from date palm midribs was that we found that the local blockboard industry in Egypt is not economically competitive, because it totally relies on imported wood, the price of which is continuously increasing. Meanwhile our research endeavors have shown that the date palm midribs being a sustainable locally available lignocellulosic resource enjoys physical and mechanical properties comparable with those for imported wood (e.g. spruce and beech). Here came the spark of rediscovery: could we replace the inner wooden core of the blockboard with palm midribs and thus save ~80% of the wood being imported for the manufacture of blockboards in Egypt? The research results have proven that the date palm midrib core blockboard enjoys excellent quality as compared with the wooden-core blockboard according to DIN standards and can be thus used as a substitute for spruce-core blockboards in furniture, wall and ceiling paneling, containers etc.

A research (Ashori, A. (2010). Hybrid Composites from Waste Materials. Journal of Polymers and the Environment, 18(1), 65–70. https://doi.org/10.1007/s10924-009-0155-6)has been conducted on the use of date palm petioles as a sandwich core. The petioles constitute the bases of the date palm leaves and are most dominantly treated as waste. But the petiole is very anisotropic with the best mechanical properties in the longitudinal direction, having a limited density and thus a high fatigue life. Proceeding from the above research results and the almost zero-price of the date palm petioles in the sites of date palm plantations, they are a good candidate for the development of core for sandwich panels.

Given the decline in plywood manufacturing world-wide due to limited large log supply, the oriented strand board- being typically manufactured from fast-growing small tree species- is one of the world's most commonly used engineered wood-base panel products in residential construction. In a pioneer study (Hegazy, S. S., & Aref, I. M. (2010). Suitability of Some Fast-Growing Trees and Date Palm Fronds for Particleboard Production. Forest Products Journal, 60(7), 599–604. https://doi.org/10.13073/0015-7473-60.7.599)date palm midribs from barhi, saqui, khalas and sukkari cultivars were used in making untreated strands to manufacture oriented strand boards with acceptable physical and mechanical properties.

Within the framework of a research (Hamed El-Mously., *rediscovering date palm by-products: an opportunity for sustainable development, keynote lecture, the first international conference for palm by-products,* 2018.)) conducted on the use of date palm products of pruning in the manufacture of MDF, samples of products of pruning were collected with quantities proportional to those obtained during the traditional pruning activities in Bahariah oases in Egypt. These samples were sent to the laboratories of Naga Hammady Company of Fiber Boards (MDF) in Egypt. The results of tests of physical and chemical properties, conducted according to EN322, EN317, EN120 and mechanical properties, conducted according to EN310; EN319; EN311 prove that it is possible to manufacture MDF boards from date palm products of pruning satisfying the international standards with respect to their physical, chemical and mechanical properties. This opens the potentiality- worldwide- to establish MDF industrial projects in locations having extensive date palm plantations.

Within the framework of research (Hamed El-Mously., *rediscovering date palm by-products: an opportunity for sustainable development, keynote lecture, the first international conference for palm by-products,* 2018.)) on the potentiality of production of particleboards from date palm midribs, two semi industrial experiments have been conducted. The first industrial experimental was conducted in October, 1993 on 1.15 tons of air-dried date palm midribs in the Nasr Company for particleboards in Egypt according to the Egyptian standard 906/1991 for particleboards. The results of tests of the modulus of rupture was 30.3 N/mm^2 satisfying the requirements of the above mentioned standard. The second industrial experiment was conducted in August, 1994 on 60 tons of air-dried date palm midribs in the Modern Arabian Company for Industry of Wood. The experiment on 100% date palm midrib boards gave the following results:

- Density: 0.844 gm/cm^3
- Modulus of rupture: 21.9 N/mm^2
- Face strength: 1.07 N/mm^2
- Internal bond: 0.9 N/mm^2

A research (Said S. Hegazy, Ibrahim M. Aref, Hamad Al-Mefarrej and Lotfy I. El-Juhany. (2008). Effect of Spacing on the Biomass Production and Allocation in Conocarpus erectus L. Trees Grown in Riyadh, Saudi Arabia. Saudi Journal of Biological Sciences, 15(2), 315– 322.) has been conducted on the potentiality of production of particleboards from date palm midribs. Date palm leaves were collected from Barhi, Saqie and Sukkari cultivars in Riyadh, Saudi Arabia. To manufacture particleboard panels, dried particles were blended with urea-formaldehyde resin 10% (oven dry particle weight), 1% liquid paroffin wax, as well as ammonium chloride as a hardener (2% based on the hard resin weight). From the results of tests it can be concluded that the date palm midribs can be used for the manufacture of particleboards.

Another research (Hegazy, S., & Ahmed, K. (2015). Effect of Date Palm Cultivar, Particle Size, Panel Density and Hot Water Extraction on Particleboards Manufactured from Date Palm Fronds. Agriculture, 5(2), 267–285. https://doi.org/10.3390/agriculture5020267.) has been conducted on the potentiality of use of fast growing tree species (e.g. A.Saligna, C.erectus L and M.azedarach L.) and date palm midribs for the manufacture of particleboards. As a conclusion of this research all the tested species can be used for the manufacture of particleboards of density 750 kg/m^3. A research (Sain, M., & Panthapulakkal, S. (2006).

Bioprocess preparation of wheat straw fibers and their characterization. Industrial Crops and Products, 23(1), 1–8. https://doi.org/10.1016/j.indcrop.2005.01.006) has been conducted to evaluate the potentiality of use of the date palm midribs for the production of particleboards. Date palm midribs were collected from local areas in Quena governorate, south of Egypt, cut into small strips and then converted into small chips 25x25x5 mm. Three-layer particleboards 400x400x12 mm with density 680 kg/m^3 were produced at a pressure 35 kg/cm^2. The results of tests proved that the date palm midrib panels have satisfied the requirements of load-bearing boards for use in dry conditions type (p4) of the European standard(EN 314.2010). This opens a wide potentiality of use of such an available renewable resource in manufacture of a value added product as particleboards. Another study (Monica Ek, Gellerstedt G., Henriksson G. (2009).

Pulp and Paper Chemistry and Technology. In Wood Chemistry and Wood Biotechnology (Vol. 1).) has been conducted to test the potentiality of use of date palm midribs considered as waste and vemiculite (as an inorganic filler) in the manufacture of particleboards. Midribs were obtained by defoliation of date palm leaves obtained from Kerman region in Iran, cut to suitable lengths (30- 40 cm) and air-dried. A hammer mill was then used to cut them into pieces of 15 mm length, 2 mm width and 0.4 mm thickness. A sample of vermiculate commercially available in Iran was used in micro and nano size.

Experimental panels were manufactured with resin content 10%, hardener content 2%, press closing rate 6 mm/s, press pressure 35 kg/cm², press temperature 175°C, board thickness 15 mm and target density 0.75 g/cm3. The experimental values were: number of layers (single-and 3-layer), the size of vermiculate particles (micro and nano). The research results have led to the conclusion that date palm midribs are potentially feasible for the manufacture of particleboards for indoor applications, to absorb noise, preserve the temperature of indoor living spaces as a substitute for wooden boards.

An important study (Amirou, S., Zerizer, A., Pizzi, A., Haddadou, I., & Zhou, X. (2013). Particleboards production from date palm biomass. European Journal of Wood and Wood Products, 71(6), 717– 723. https://doi.org/10.1007/s00107-013-0730-3) has been conducted to evaluate the potentiality of use of date palm trunks and midribs in the manufacture of particleboards as a substitute for imported wood.

Date palm trunks and midribs were sourced from a local plantation in south Algeria, reduced to a particle size 1-2 cm, oven dried at 100 °C to reach a MC of 3%. To manufacture the particleboard specimens the chips were placed in a drum blender and sprayed with phenol formaldehyde or melamine-urea formaldehyde for 1min. The resin content was 10% based on dry particle content. The panels were produced at a density 0.7 g/cm³. The test panels reached after trimming 320x270x14 mm³. The total press time was 7.5 min and temperature 195 °C. Proceeding from the research results it can be concluded that the manufacture of particleboards from date palm trunks and midribs is technically feasible. It is worth noting that the particleboards produced from the trunk enjoy significantly higher MOR, MOE and 1B values as compared with those for midribs. This opens a great potential for use of a new material resource (old unproductive date palm trunks) for a high value-added product such as particleboards.

Research (Saadaoui, N., Rouilly, A., Fares, K., & Rigal, L. (2013). Characterization of date palm lignocellulosic by-products and self bonded composite materials obtained thereof. Materials & Design, 50, 302–308. https://doi.org/10.1016/j.matdes.2013.03.011) has also been conducted on self-bonded particleboards from date palm products of pruning. The rationale behind the idea of self-bonding particleboards is the dispensing with the synthetic resins, the presence of which hinders the recycling of the products at the disposal stage. To conduct this study samples of date palm leaflets, midribs, petioles and fibrillum were sourced from Marrakesh province in Morocco, hammer milled, sieved by 3-mm sieve and oven-dried at 105 °C for 12h.

The self-bonding was successful: all samples were cohesive. The fibrillum boards enjoyed the highest MOR and MOE properties (12.9 N/mm² and 1257N/mm² respectively). This can be explained by the high lignin content in the fibrillum (the lignin plays an important role as a binder forming a coherent thermosetting matrix during board manufacture gluing particles togethers). The panels of leaflets and midribs had the second highest MOR values of 8.4 and 8.5 N/mm² respectively. This can be explained by the highest amount of hemicelluloses in midribs and highest content of extractives in leaflets, beside its average content of hemicelluloses.

4.5 Date palm Byproducts in Constriction, Isolation and Building Materials

This section reviews several scientific breakthroughs that have tackled the potential of utilizing date palm byproducts for various uses in contemporary construction field as a sustainable and renewable alternative to conventional materials such as concrete and steel. The date palm byproducts in construction can be used in the natural and processed form. Using date palm midribs in their natural form for light structures was investigated by several studies that showed clear loyalty to traditional techniques whose continuing thriving to the present day indicates their compatibility with the material while sustaining low-cost production. In addition, date palm midribs and trunk were investigated to be used to produce facades and structural sandwich panels. On the other hand, other researches focused on processing date palm byproducts fibers to be used in more sophisticated fields such as reinforcing concrete, high strength concrete, and mortar to enhance shrinkage resistance and ductility. In addition, the superior insolating properties of date palm fibers led to their involvement in several researches specialized in producing insolation materials, polyester composites and insolating panels which are highly in demand globally to reduce the cooling loads and heating loads and improve the indoor air quality of residential and office spaces. Moreover, crushed date palm midribs ash, midribs and petioles fibers have been introduced as a recommendable stabilizer for traditional building materials such as raw earth blocks and compressed blocks.

4.6 Date palm Byproducts in Organic Fertilizers, Compost and Soil Amendment and Coal

Grinded date palm trees mulch applications have additional benefits of decreasing water evaporation from the soil surface, helping control weed invasion, dust suppression, helping prevent soil erosion loss by wind or water and providing thermal stabilization by keeping soil cooler in hot weather and warmer in cool weather. In an important study (Ashhab A O Al. (2012). Composting mulch of date palm trees through microbial activator in Saudi Arabia. https://doi.org/10.13140/RG.2.2.21664.92169) the composting of date palm trees mulch, produced from grinded date palm leaves, trunks and roots and fresh cow manure was investigated and analysed in AL Hofuf Stars Recycle Station of AL Hasa City, K.S.A. The composite compost mixtures were built by mixing date palm mulch as a carbon source with fresh cow dung as a nitrogen source with C/N ratio 44.3:1, 50:1 and 44:1 for the mixture 1, 2 and 3 respectively. The turned windrow method has been applied in the composting process. The obtained organic fertilizer had natural soil odor and was brown in color. Thus it can be concluded that the date palm mulch can be biologically recycled into an organic product having the criteria of organic fertilizers, soil stabilizers and soil plantation. Another research (Ali, Y. S. S. (2008). Use of Date Palm Leaves Compost as A Substitution to Peatmoss.

American Journal of Plant Physiology, 3(4), 131–136. https://doi.org/10.3923/ajpp.2008.131.136) was conducted with the objective of preparing local farm residues, such as date palm leaves (DPL) as a substitute for imported peatmoss. DPL compost has been prepared according to Abu-Alfadhal method with some modifications. Air-dried DPL were cut to pieces of 10 cm length and buried in 2x1m size concrete pit of depth 1.1m. The compost layers were ~ 25 cm deep.

There were 4 identical layers of DPL up to 1m in height. The compost layers were stirred after 6 weeks followed by remixing the compost layers with an interval of 3 weeks. The compost pit was opened after 6 months and the completely decomposed date palm leaves (compost) was separated from the undecomposed part. The results of the germination experiment in the first growing season showed that there was no significant difference in the number of seeds germinated in the DPL compost and peatmoss. In the second growing season the total number of seeds germinated were significantly higher in the DPL compost than peatmoss. In conclusion, the date palm leaves compost is an excellent substitute for peatmoss.

Another study (Abid, W., Magdich, S., Mahmoud, I. B., Medhioub, K., & Ammar, E. (2018). Date Palm Wastes Co-composted Product: An Efficient Substrate for Tomato (Solanum lycopercicum L.) Seedling Production. Waste and Biomass Valorization, 9(1), 45–55. https://doi.org/10.1007/s12649-016-9767-y) has been conducted to evaluate the feasibility of using composted date palm residues as a growth medium for tomato greenhouse plants production. Compost was prepared by mixing goat manure with crushed date palm residues (1:3 v/v). The date palm residues were sourced from the oasis of Cheneni (Gabes) and the goat manure from a local organic farm in Gabes (south of Tunisia). The windrow of 7 tons was irrigated by well water having pH 7.08 and electrical conductivity 3.4 mS/cm. The obtained compost was then evaluated for its effects on the growth of Riograndi tomato seeds under greenhouse conditions at a local nursery in Sfax (south of Tunisia). The ingredients of the windrow were mixed by mechanical rotation to allow for aeration. The mature compost was ready after 6 months of adequate aeration and humidification. The produced compost from date palm leaves and goat manure co composting had a pH value within the range of 6.0-8.5 and electric conductivity value lower than 3mS/cm and is thus compatible with most plants growth needs. In addition the final C/N ratio value indicated the complete biodegradation and the stability of the substrate. The produced compost seems to be the most efficient for tomato seedling, especially leaves numbers when used at 30% in the substrate. Thus it can be concluded that the date palm residues co composting could provide a viable ecological and sustainable alternative to conventional fertilizers. Another study (Elouaqoudi, F. Z., El Fels, L., Amir, S., Merlina, G., Meddich, A., Lemee, L., Ambles, A., & Hafidi, M. (2015). Lipid signature of the microbial community structure during composting of date palm waste alone or mixed with couch grass clippings. International Biodeterioration & Biodegradation, 97, 75–84. https://doi.org/10.1016/j.ibiod.2014.08.016) has been conducted with the objective of achieving a better understanding of the microbial assemblages involved in the composting of lignocellulosic residues and to estimate the diversity of the microbial community structures responsible for the biodegradation.

This has been achieved by analysing the composition of the lipid fraction and following qualitative and quantitative variations in the levels of different fatty acid methyl esters (FAMEs) identified during composting. The study of compost's organic matter composition has been considered important to understand how bio-waste can be processed. Various authors devoted their endeavors to study the humic substances. These lipids, formed during the biotransformation of organic matter by composting provide useful information about the compost's maturity and stability and play an important role in soil processes. These compounds, mainly of plant and microbial origin are hydrophobic and are often extracted with humic substances.

A study (M. M.A. Abdelsamie. (2018). A Study of the Potentially of Use of the Date Palm Midrib in Charcoal Production [Master]. Engineering, Ain Shams University.) has been conducted with the objective of evaluating the potentiality of use of the date palm midrib in charcoal production. The date palm midribs being a product of annual pruning of date palms are extensively available in most of the governorates in Egypt. Charcoal is needed as a fuel beside its environmental, medical and industrial applications. To conduct this study samples of date palm midribs were collected from two date palm varieties: Baladi and Siwei from EL-Qayat village, Menia governorate, Egypt. Each date palm midrib was divided into end, knee, base, middle and top parts. A pyrolysis reactor has been designed and manufactured. The carbonization cycle to 500 °C was conducted according to FAO standard with a heating rate 5-7 °C/min for Baladi and Siwei date palm different parts. The experimental analysis has been conducted according to ASTM standards including the calorific value, fixed carbon, volatile matter%, ash content%, sulfur content% and moisture content% for the date palm midrib parts before and after carbonization. The research results show that for Balady midribs the best samples according to FAO standards are the middle part of the followed by the top, base, knee and end. Regarding Siwei midribs the best samples are the top part of the midrib followed by the base, middle and end. Taking the whole midrib into consideration Balady and Siwie midribs realized 86% and 88% of the FAO standard respectively. Thus it can be concluded that the Balady and Siwei date palm midribs can be used for the manufacture of charcoal suitable for environmental, medical and industrial applications.

A research (Usman, A. R. A., Abduljabbar, A., Vithanage, M., Ok, Y. S., Ahmad, M., Ahmad, M., Elfaki, J., Abdulazeem, S. S., & Al-Wabel, M. I. (2015). Biochar production from date palm waste: Charring temperature induced changes in composition and surface chemistry Journal of Analytical and Applied Pyrolysis, 115, 392–400. https://doi.org/10.1016/j.jaap.2015.08.016) has been conducted with the objective of investigating the effect of pyrolysis temperature on date palm derived biochar characteristics to use it for agronomic or environmental management.

Biochar- as a stable carbon enriched materials- is produced by thermal conversion using unstable carbon enriched materials. Date palm products of pruning were sourced from a farm near to Riyadh city in Saudi Arabia including leaves and spadix stems. The samples were pyrolysed to temperatures 300,400,500,600,700 and 800 °C at a rate of 5 °C/min. The proximate analysis of the samples has been conducted according to ASTM 1762-84 standard method including moisture, ash and volatile matter in biochar. The research results showed that the highest yield of biochar was achieved at the lowest pyrolysis temperature (300 °C). The fixed C, ash and basic cations of biochar increased while its moisture, volatiles and elemental composition (O,H,N and S) decreased with increasing pyrolysis temperature. Biochars produced at high temperature (> 500 °C) could be more resistant to mineralization through biological processes than biochars pyrolyzed at lower temperature (<500 °C), thus becoming more effective in mitigating greenhouse gas emission into the environmental. It could be concluded that the date palm biochars produced at low pyrolysis temperature (300-400 °C) that are practically carbonized and have relatively high organic functional groups and lower alkalinity may improve the fertility of arid soil more than those pyrolyzed at high temperature (700 and 800 °C). Thus the research results may lead to the conclusion that the biochars produced from date palm products pf pruning represent a potential alternative materials for agronomic or environmental management.

4.7 Date Palm Byproducts for Natural Fodder and Silage

Waste dates (most dominantly treated as waste) representing ~20- 30% of total dates production has been used as a replacement of dietary starch in tilapia feed. This has led to the improvement of growth rate, feed conversion, specific growth rate and protein efficiency ratio. In another study (O. Sotolu, A., A. Kigbu, A., & J. Oshinow, A. (2014).

Supplementation of Date Palm (Phoenix dactylifera) Seed as Feed Additive in the Diets of Juvenile African Catfish (Burchell, 1822). Journal of Fisheries and Aquatic Science, 9(5), 359–365. https://doi.org/10.3923/jfas.2014.359.365) the addition of date palm seed- most dominantly treated as waste- to the diet of the African catfish has led to a considerable increase of the weight gain, specific growth rate, protein efficiency ratio and protein productive value, as well as the improvement of final fish carcass and hematological indices. The improved growth rate and nutrient utilization could be explained by the presence of a range of digestive enzymes in the date palm seeds. A research (Bahman, A. M., Topps, J. H., & Rooke, J. A. (1997). Use of date palm leaves in high concentrate diets for lactating Friesian and Holstein cows. Journal of Arid Environments, 35(1), 141–146. https://doi.org/10.10 06/jare.1995.0145) has been conducted in Kuwait to evaluate the technical feasibility of use of the locally and sustainably available date palm leaflets as a roughage to substitute the imported barley straw in feeding of Friesian and Holstein cows. The results of feeding experiments revealed that milk yields, milk composition and live weight gains of cows fed by either date palm leaflets or barley straw did not significantly differ.

Therefore it can be concluded that the date palm leaflets- a local sustainable resource treated as waste- can be used as an a acceptable alternative roughage in feeding of cows to the expensive imported barley straw. Anther research (Baroon, Z., El-Nawawy, A. S., & Al-Othman, A. (2004). Ensilage of Cardboard and Date Palm Leaves.

Journal of Environmental Science and Health, Part A- Toxic/Hazardous Substances & Environmental Engineering, 39(2), 515–533. https://doi.org/10.1081/ESE-120027542) was devoted to the evaluation of ensilage, made from cardboxes, annually available with about 100000 tons in Kuwait and date palm leaves resulting from annual pruning of date palm and treated as waste. The bioconversion and upgrading of nutritive value of cardboxes and date palm leaves to silages were investigated over 09 days through chemical and microbial treatments. The qualitative aspects of the produced silages for ruminants were evaluated. It can be concluded from the research results that cardboxes and date palm leaves can be effectively ensilaged and the resultant silages are acceptable and palatable to be used as ruminant feed in arid regions. A research (Mahgoub, O., Kadim, I. T., Al-Busaidi, M. H., Annamalai, K., & Al-Saqri, N. M. (2007).

Effects of feeding ensiled date palm fronds and a by-product concentrate on performance and meat quality of Omani sheep. Animal Feed Science and Technology, 135(3–4), 210–221. https://doi.org/10.1016/j.anifeedsci.2006.07.011) has been conducted to evaluate the potentiality of use of date palm leaves for feeding of Omani sheep.

Oman and the whole gulf region suffer as an arid region from the shortage of animal feed representing an obstacle in livestock investment projects. This study has been conducted on 32-1 year-old male Omani native sheep of starting body weight ~32 kg in a feeding trial for 120 days.

The conducted feeding included two types of roughages: Rhodes grass hay (RGH) and urea-treated date palm leaves (UTPF). The experimental animals fed by the date palm leaves were in good health throughout the trial. But the sheep fed by UTPF had lower feed intake as compared with those fed by RGH, but feed intake/body weight was similar across diet groups. Therefore date palm leaves can be used as a component of feed for Omani sheep in case of nutritional shortage frequently experienced in arid zones.

A research (Mahgoub, O., Kadim, I. T., Al-Busaidi, M. H., Annamalai, K., & Al-Saqri, N. M. (2007). Effects of feeding ensiled date palm fronds and a by-product concentrate on performance and meat quality of Omani sheep. Animal Feed Science and Technology, 135(3–4), 210–221. https://doi.org/10.1016/j.anifeedsci.2006.07.011) has been conducted in Algeria to evaluate, in vitro, the ruminal fermentation and nutritive value of the date palm leaves, pedicels, date-pits and waste dates. To conduct this study, 20 to 30 specimens of leaves, pedicels and date-pits were taken from Deglet-Nour palm and waste dates from three varieties Bourus, Harchaya and Kentichi in Biskra in Saharan Atlas region in Algeria. Vetch-oat hay was taken as a control reference. All the samples including the control were oven-dried at 50 °C and ground to pass 1mm screen. The results of this research showed that the date palm leaves have the highest NDF, ADF, lignin and crude protein contents (609, 435, 84, 649 $kg^{-1}DM$) respectively.

The cumulative gas production at 144h of incubation was greatest for Kentichi dates (330 $mLg^{-1}DM$) and lowest for date pits(69 $mL^{-1}DM$). Regardless of the variety, waste dates showed the highest DM effective ruminal degradability and organic matter digestibility. The date-pits seemed to be a poorly degradable material. These results indicate that waste dates- though of low protein content- are highly digestible with energy concentration as high as that of vetch-oat hay. The palm leaves and pedicels can be considered as highly fibrous emergency roughages for low-producing animals. Protein supplements should be added when date palm byproducts are used as feedstuff in order to balance the ruminant diets.

An important (D. Genin, A. Kadri, T. Khorchani, K. Sakka, F. Belgacem and M. Hamadi. (2004). Valorisation of date-palm by products (DPBP) for livestock feeding in Southern Tunisia. I – Potentialities and traditional utilisation. CIHEAM Options Méditerranéennes, 221–226.) study has been conducted with the objective of learning about farmer's knowledge south of Tunisia on the use of date palm byproducts (DPBP) as forage resources. To conduct this study, samples of wasted dates, date pits, leaves, peduncles and pedicels of two dominant varieties (Deglet Nour and Kentah) were taken and analysed for dry matter, crude protein, total ash, crude fiber, natural detergent fiber, acid detergent fiber and acid detergent lignin. The in vitro digestibility measurements have been taken on each sample using rumen juices from three species: sheep, goat and dromedary. An extensive socio-economic survey has been conducted in a sub-region of Nefazoua (EL Faoura) concerning the use of DPBP in livestock feeding. It can be concluded from the results of this study that DPBP, taken individually are highly unbalanced for animal nutrition: high energy content in the cases of wasted dates and date-pits and high fiber content for leaves, peduncles and pedicels and for all: low crude protein content (3 to 6.5% of dry matter).

The in vitro dry matter digestibility for wasted dates were found 74.5, 79.7 and 79.2% for sheep, goats and dromedary respectively. The corresponding figures for leaves, peduncles and pedicels were found much lower: 12.3, 19.6 and 18.3% respectively. Thus, the main questions to be asked in use of DPBP in ruminant feeding are how to make a well-balanced DPBP based forage? And how to conserve this feed to overcome the problem of seasonal unavailability? This indicates the significance of research on DPBP-based silage to improve the technical and economic feasibility of use of DPBP as a local and sustainable forage resource.

An important study (Rajaee Rad, A., Ahmadi, F., Mohammadabadi, T., Ziaee, E., & Polikarpov, I. (2015). Combination of Sodium Hydroxide and Lime as a Pretreatment for Conversion of Date Palm Leaves into a Promising Ruminant Feed: An Optimization Approach. Waste and Biomass Valorization, 6(2), 243–252. https://doi.org/10.1007/s12649-014-9340-5) has been conducted to evaluate the effectiveness of a combined treatment of date palm leaves by sodium hydroxide and lime for conversion into a promising ruminant feed. Date palm leaves (DPL), annually available in Iran with big quantities (e.g. 300000 to 400000 t) are being treated as waste!

One of the approaches to solve this problem is to use DPL in feeding of ruminants. But DPL in its natural form has a very low ruminal digestibility (16% in vitro dry matter digestibility). The alkaline pretreatment of DPL to improve the ruminal degradability at high temperature is fast and effective, but it is a capital intensive process.

Therefore the idea of this research was to replace only a part of costly sodium hydroxide with less expensive lime to realize a cost- effective and efficient pretreatment of DPL at a mild temperature with low concentration of sodium hydroxide.

To conduct this study DPLs were collected in Jam country in Busher province in Iran. Raw milled DPLs were pre-washed and 10g, dry matter basis was mixed with a solution of sodium hydroxide and lime at a 1:8 solid-to- liquid ratio in a 250 ml bottle, purged with N_2 stream (60s) to remove probable Co_2 in headspace which may react with lime, tightly closed and stirred at 500 rpm for 10 min. The statistical analysis of results revealed that the impact of sodium hydroxide, lime and residence reaction time is significant ($p< 0.0001$).

Under the optimum pretreatment conditions (sodium hydroxide loading 0.06 g NaOH/g dry biomass, lime loading of 0.09 lime/g dry biomass and residence time 71.4h), the amount of cumulative gas production after 24h was 101.4 ml gas/g organic matter, versus 104.6 ml gas/g organic matter for the predicted value. Thus the results of this study prove the applicability of this low-cost efficient on-farm pretreatment to overcome the recalcitrance of date palm leaves and hold a promise to use date palm leaves- this dominantly wasted resource- for feeding of ruminants particularly in arid and semi-arid regions.

4.8 Date Palm Byproducts for Waste Water Treatment

The pollution, caused by heavy metals, phenols and phenolic compounds, as well as synthetic dyes and pesticides is an environmental problem of world concern. A research (El-Shafey, E.-S. I., & Al-Kindy, S. M. Z. (2013). Removal of Cu^{2+} and $Ag^{+}$from aqueous solution on a chemically-carbonized sorbent from date palm leaflets. Environmental Technology, 34(3), 395–406. https://doi.org/10.1080/09593330.2012.698647) has been devoted to the use of a sorbent made from date palm leaflets for the removal of Cd^{2+} and $Ag^{+}$from waste water. The date palm leaflets are annually available from pruning of date palms with big quantities: 180000 ton and 3 million tons in Oman and the gulf states respectively. Palm leaflets were sourced from a farm in Muscat (Oman), washed with distilled water, left to be air-dried and then oven-dried to constant weight. The sorption of Cd^{2+} and $Ag^{+}$from aqueous solutions was investigated, taking the following parameters into consideration: pH value, contact time, metal concentration and temperature. The sorption behavior was different for both metals. The sorption of Cd^{2+} was fast reaching equilibrium within ~2h, whereas that for Ag^{+} was slow and required ~60h. The research results has led to the conclusion that the date palm leaflets, generally of no value in the field and treated as waste, can be successfully used to make a chemically-carbonized sorbent for the removal of cupper and silver metals from the waste water. Anther research (Al-Ghamdi, A., Altaher, H., & Omar, W. (2013). Application of date palm trunk fibers as adsorbents for removal of Cd+2 ions from aqueous solutions. Journal of Water Reuse and Desalination, 3(1), 47–54.) was conducted to investigate the potentiality of use of raw date palm trunks for the removal of cadmium from waste water. The effects of the process variables, such as fiber size, mixing rate, temperature, pH of the solution and absorbent dose on the absorption capacity of trunk fibers were studied. It was found that the adsorption capacity of Cd^{2+} increased from 29.06 to 51.1 mg/g (~2 times) as the particle size decreased from 875 to 100 µm.

Concerning the effect of pH value, it was found that the adsorption capacity of Cd^{2+} decreased in the strong acidic medium and rapidly increased as the pH of the solution increased from 1.69 to 3.71. It was found that the equilibrium time of adsorption process is very small: the maximum adsorption capacity was attained only after 10 min. Thus, it can be concluded that the date palm trunk fibers are a potential absorbent for the removal of cadmium from waste water. This opens a great economic and developmental potentiality of use of the trunks of the old and unproductive date palms as a low cost material for the removal of Cd^{2+} and other toxic metals from the waste water. A research (Islam, Md. A., Tan, I. A. W., Benhouria, A., Asif, M., & Hameed, B. H. (2015). Mesoporous and adsorptive properties of palm date seed activated carbon prepared via sequential hydrothermal carbonization and sodium hydroxide activation. Chemical Engineering Journal, 270, 187–195. https://doi.org/10.1016/j.cej.2015.01.058) has been conducted on the use of date palm seeds for the production of activated carbon via sequential hydrothermal carbonization (HTC) and sodium hydroxide activation. HTC is a distinguished low temperature and environmentally favorable process. To conduct this study, the date palm seeds (PDS) were locally obtained in Malaysia. An automated stainless-steel hydrothermal reactor of capacity 200 ml was used for HTC and a sample of 5g was put in it. The reactor was sealed and heated to 200°C for 5h at 5 °C/min heating rate. After cooling, the obtained hydrochar was well washed with distilled water and put in an oven at 105 °C for 24h. The PDS-HTC hydrochar was impregnated with NaOH at ratios of PDS-HTC: NaOH (w/w): 1:1, 1:2 and 1:3, then oven-dried at 105 °C for 24h. Then an automatic electric vertical furnace was used to activate the NaOH pretreated hydrochar at 600 °C under a continuous nitrogen (N_2 99.995%) flow at 150 cm3/min. A 10 °C/min rate of heating was set for 1h. The produced AC was collected after cooling, repetitively rinsed with hot distilled water to decrease the pH of the washing solution from 6to 7. Then the ACs were dried in an oven at 105 °C for 24 h and stored in tightly closed container.

The methylene blue (MB) was chosen in this study for the evaluation of the adsorption performance of the PDS hydrochar AC in aqueous solution. The textural, morphological and chemical properties of the produced hydrochar AC were investigated. NaOH activation enhanced the porosity and surface functionality of the hydrochar. Thus the prepared AC exhibited a relatively high specific surface area of 1282.49 m^2/g, a total pore volume of 0.66 cm^3/g and an average pore width of 20.73 Å. Thus, it can be concluded that it is feasible by a combination of HTC and NaOH activation to produce activated carbon with remarkable adsorptive properties from date palm seeds, a very cheap resource, dominantly treated as a waste. A research (Suresh Kumar Reddy, K., Kannan, P., Al Shoaibi, A., & Srinivasakannan, C. (2014). KOH-based porous carbon from date palm seed: Preparation, characterization, and application to phenol adsorption. Water Science and Technology, 70(10), 1633–1640. https://doi.org/10.2166/wst.2014.419) has been conducted on the use of date palm seeds for the removal of phenol. The date palm seeds were received from a local farm in Abu Dhabi, washed with deionized water, dried at 105 °C for 24h, ground to size >500μm and stored in a desiccator. Ten grams of the material was mixed with KOH (40% by volume) solution at an impregnation ratio (KOH/biomass) of 2. The produced porous carbon had a Brunauer-Emmett-Teller area of 892m^2/g, pore volume of 0.45 cm^3/g and average pore diameter of 1.97 nm.

This porous carbon was used for the adsorption of phenol at different concentrations (100-400 mg/L) and temperatures (30-50°C). The adsorption behavior of phenol on porous carbon was found to be well described by Langmuir isotherm model. The mono layer adsorption capacity was found to be 333 mg/g, the highest as compared with date palm seed biomass-based porous carbons. Thus, it can be concluded that it is feasible to use date palm seeds for the preparation of KOH based activated carbon for the removal of phenol from aqueous solutions as a low-cost process with an extremely high performance.

An important paper (Ahmed, M. J. (2016). Preparation of activated carbons from date (Phoenix dactylifera L.) palm stones and application for wastewater treatments: Review. Process Safety and Environmental Protection, 102, 168–182. https://doi.org/10.1016/j.psep.2016.03.010) has been devoted to a review on the preparation of activated carbons from date palm stones and application for waste-water treatments. The agricultural residues have withdrawn the attention of researchers as promising precursors for activated carbon, because of the low-cost, great abundance, renewability and high lignocellulosic content. Fruit stones are of particular interest being byproducts of food industries and thus easy to collect. Examples of these fruit stones are peach, apricot, olive, cherry, grape and date stones.

Among these fruit stones, the date stones are especially distinguished for their high carbon content, low price and high availability in the Arab countries. The date stone represents ~10% of the fruit weight making it the largest agricultural byproduct in the date producing countries (~700 thousand tons annually). Chemical activation is preferred over physical due to higher yield, single step treatment, lower temperature, shorter time and better porous structure. Among the different methods of waste water treatment the adsorption is advantageous because of its simplicity, flexibility, suitability for batch and continuous processes, possibility of regeneration and reuse, low expenses and capability to remove a wide array of pollutants in different concentrations. The activated carbon is distinguished with a high adsorption performance due to its high surface area, well-developed porous structure and favorable surface properties. The chemical composition of date stones is as follows: moisture (5-10%), ash (1-2%), protein (5-7%), oil (7-10%), crude fiber (10-20%) and carbohydrates consisting of 23% hemicellulose, 15% lignin, 57% cellulose and 5% ash. The activation variables affecting the pore characteristics and yield of carbon are in the order of: activation temperature, impregnation ratio and activation time. The surface areas of date stone-carbons were in the range from 490 to 1282 m2/g and yields from 17 to 47% with the highest values obtained by chemical activation. The application of date palm stones-carbons for the adsorption of organic and inorganic pollutants demonstrated maximum capacities of 612.1, 359.1, 238.1 and 1594 mg/g for dyes, phenols, pesticides and heavy metals respectively. Thus it can be concluded that the date palm stones are a low-cost, renewable, non-toxic and biocompatible source for the manufacture of activated carbon of high efficiency for removal of pollutants from waste water.

Proceeding from the insufficiency of literature on the use of date palm seeds as a suitable precursor for the manufacture of activated carbon a research (Suresh Kumar Reddy, K., Shoaibi, A. A., & Srinivasakannan, C. (2015). Impact of process conditions on preparation of porous carbon from date palm seeds by KOH activation. Clean Technologies and Environmental Policy, 17(6), 1671–1679. https://doi.org/10.1007/s10098-014-0875-8) has been conducted to investigate the impact of process conditions on the preparation of porous carbon from date palm seeds using KOH activation. To conduct this study, date palm seeds were sourced from a local farm in Abu

Dhabi, UAR, washed with deionized water and dried in oven at 105 °C for 24h and then ground to a particle size >500 µm. Ten grams of date palm seeds dust were mixed with KOH (40% by volume) solution at an impregnation ratio 1-5. The mixture was stirred for 5h using a magnetic paddle. After complete soaking of KOH solution the mixture was oven-dried at 105 °C and then activated at a horizontal furnace at 500-900 °C for an activation time 30-120 min in a nitrogen flow of 150 mL/min. The carbonized samples were cooled to room temperature in an inert atmosphere, washed with HCI aqueous solution to remove ash and then by distilled water to reduce pH to neutral. The final porous carbon was then dried at 105°C for 12 h. The yield of activated carbon was estimated based on grams bone dry per grams bone dry of date palm seeds.

The results of the study have come to the following conclusions:

1. The increase of the activation temperature and the impregnation ratio (KBR) contribute to the increase of the BET surface area, while the yield decreases.
2. The activation duration was found not to influence the BET surface area and its effect on the yield is marginal.
3. The optimum conditions were found as follows: activation temperature 601 °C, KBR ratio 1.97 with the corresponding BET surface area and yield being 910 m^2/g and 22.9%. The activated carbon possessed a pore volume of 0.45 cc/g, an average pore diameter of 1.54 nm with the micropore volume proportion being 0.40 cc/g.
4. The activated carbon textural characteristics have a microporous nature. It has been also tested for iodine adsorption.
5. 5It was found that the date palm seeds activated carbon contains a large number of acid functional groups in the form of carboxylic and hydroxyl groups and thus could be effectively utilized for the treatment of waste water.

4.9 Date Palm Byproducts for Green Fuels and Bioenergy Production

The annual products of pruning of date palms are predominantly treated as waste: either open-field burnt or sent to landfills. The date palm leaves representing ~54.6% by weight of products of pruning have been successfully used for production of bioethanol with a 60% yield using the simulatanous treatment by 3 enzymes: laccase for lignin degradation, xylanase for hemicellulose hydrolysis and cellulase for cellulose hydrolysis.

In anthor study (Cybulska, I., Brudecki, G. P., Zembrzuska, J., Schmidt, J. E., Lopez, C. G.-B., & Thomsen, M. H. (2017). Organosolv delignification of agricultural residues (date palm fronds, Phoenix dactylifera L.) of the United Arab Emirates. Applied Energy, 185, 1040–1050.) the organoslov process has been successfully used to extract lignin and digestible cellulose pulp from date plam leaves for the production of bioethanol. The maxiumam practical yield of bioethanol was 9.92 g ethanol/100g raw material representing 90.95% of the theoretical value.

Aceton, butanol and ethanol are common solvents used in many important industries and thus can replace energy derived from petrochemicals. A study (Abd-Alla, M. H., Zohri, A.-N. A., El-Enany, A.- W. E., & Ali, S. M. (2015). Acetone–butanol–ethanol production from substandard and surplus dates by Egyptian native Clostridium strains. Anaerobe, 32, 77–86. https://doi.org/10.1016/j.anaerobe.2014.12.008) has been conducted on the use of low-quality surplus date palm fruits as a substrate for fermentation in the production of acetone, butanol and bioethanol using the original Egyptian clostridium strains, isolated from agriculatural soil, cultivated with different plants in Assiut Governorte, Egypt.

A research (Amani, M. A., Davoudi, M. S., Tahvildari, K., Nabavi, S. M., & Davoudi, M. S. (2013). Biodiesel production from Phoenix dactylifera as a new feedstock. Industrial Crops and Products, 43, 40– 43. https://doi.org/10.1016/j.indcrop.2012.06.024) has been conducted on the biodesiel production from date palm seeds. The date seed represents 10-15% of the date fruit weight. The date seed is composed of 3.1-7.1% moisture, 2.3-6.4% protein, 5.0-13.2% fat, 0.9- 1.8% ash and 22.5-80.2% dietary fiber. According to FAO statistic 2010 the date production in south-western Asia and north

Africa can be estimated at 7.85 million tons including seeds of 785000 to 1.18 million tons. Biodiesel is generally considered as the most acceptable biofuel for diesel engines, because of its technical, environmental and strategic advantages compared with fossil-based diesel fuels, such as cleaner engine emissions, biodegradability, renewability and superior lubricating properties. In this research the biodiesel has been produced by transesterification with a yield of 98% and the fatty acid esters were analysed by GC/MS. The research results show that the fatty acid composition of biodiesel was similar to biodiesel fuels produced from other vegetable oils. The date seed biodiesel had a considerable amount of low-chain fatty acids, which gives special features to biodiesel, high cetane number (60.3), low viscosity ($3.84 mm^2/s$), flash point (140 °C) and low iodine value (46). The only weak point is its high pouring point (-1 °C), which limits its use in cold weather as compared with other vegetable biodiesel fuels.

A study (Kamil, M., Ramadan, K., Olabi, A. G., Ghenai, C., Inayat, A., & Rajab, M. H. (2019). Desert Palm Date Seeds as a Biodiesel Feedstock: Extraction, Characterization, and Engine Testing.) has been devoted to the investigation of production factors to optimize the extraction of date palm seeds oil, production of biodiesel and testing of biodiesel blends in a compression ignition diesel engine. The date palm seeds were sourced from Sharjah date facility in Sharjah (UAE). The date palm seed oil has been extracted using the Soxhlet extraction method, because it represents the most practical option for analytical scale, where parameters can be appropriately monitored and controlled. The resulting biodiesel was characterized and assessed based on widely used international standards (ASTMD6751 and EN14214). Four biodiesel blends were prepared (B5, B10, B15 and B20) and tested in a compression ignition engine at engine speeds from 1600 to 3600 rpm (200 rpm increments) and three engine loads (50%, 75% and 100%). A date seed oil biodiesel yield of 92% has been achieved at the following transesterification conditions: 55 °C, 9:1 AOMR, 1wt% CMF and 90 min. Thus the research results lead to the conclusion of fundamental suitability of date palm seeds as a biodiesel feedstock.

An important study (Taghizadeh-Alisaraei, A., Motevali, A., & Ghobadian, B. (2019). Ethanol production from date wastes: Adapted technologies, challenges, and global potential.

Renewable Energy, 143, 1094–1110.) has been devoted to the production of ethanol from date palm residues. The fermented ethanol can be produced from three groups of feedstocks: sugary, starchy and ligno cellulosic compounds. In the first generation (1G) processing, sugary and starchy feedstock is converted to bioethanol.

However (1G) processing is in contradiction with needs of humans and animals. Therefore, it is expected that (2G) production of ethanol will prevail in the near future. Bioethanol production from ligno-cellulosic biomass (G2) process is economical only if the sugar concentration exceeds 40 gL^{-1} and yield is increased. The aim of the present study is to find the optimum ways to convert the date wastes and products of pruning to ethanol and to encourage investors to invest in bioethanol production. Egypt, Iran and Saudi Arabia produce almost ½ the world's dates production with shares of world production ~20%, 14%, 14% respectively. The weight of date seeds varies between 0.5 and 4g (6- 30% of fresh fruit weight). Assuming an average of 13% of total fruit weight belongs to the seed, a weight of 120 kg dried seed per ton of date wastes can be estimated. Thus 13 kg of seed oil (10.85% by weight) can be used for biodiesel fuel production (density 0.871 kg/L).

The finding of this study show that there is a great potential to produce ethanol from date wastes and date palm products of pruning in the Middle East countries due to their high availability potential. Besides, these date wastes and lignocellulosic residues are dominantly treated as waste and thus representing a source of environmental pollution. Egypt, Iran and Saudi Arabia can produce annually 173.5, 401 and 438 million liters of bioethanol respectively from date wastes and annual products of pruning. Other date producing countries have the potentiality to produce 1248 milion liters of bioethanol. Thus 3260 million liters of bioethanol can be globally produced. The global cost of bioethanol production from date waste is 0.68$ per liter of which feedstock accounts for 85.3% of the total cost of production. The corresponding value for date palm products of pruning is 0.34$ per liter due to high availability potential.

An important research (Al-Muhtaseb, A. H., Jamil, F., Al-Haj, L., Al Hinai, M. A., Baawain, M., Myint, M. T. Z., & Rooney, D. (2016). Efficient utilization of waste date pits for the synthesis of green diesel and jet fuel fractions. Energy Conversion and Management, 127, 226–232. ht tps://doi.org/10.1016/j.enconman.2016.09.004) has been conducted on the use of date pits for the synthesis of green diesel and jet fuel fractions. Date pits were sourced from a local supplier in Muscat, Oman. A mechanical grinder was used to convert the samples to a powder. After sieving, the oil was extracted using hexane as a solvent in a Soxhlet apparatus following the AOCS official method Am 2-3. After extraction of oil a 100g sample of date pits was dried at 100 °C for 8h and then carbonized in a furnace at 500 °C for 5h with a heating rate of 3 °C/min under N_2 gas at a flow rate of 50 ml/min. Active catalysts were thus produced by carbonization and impregnation with P_t and P_d metals. The synthesized catalysts $P_{t/c}$ and $P_{d/c}$ were characterized by XRD, SEM, TEM, EDC, BET and XPS. The activity of the catalyst's performance was evaluated by hydrodeoxygenation of date pits oil. Based on the elemental analysis, the degree of deoxygenation (DOD) of product oil was 97.5% and 89.4% for $P_{d/c}$ and $P_{t/c}$ catalysts respectively. The high DOD was also confirmed by the product analysis that mainly consists of paraffinic hydrocarbons. The results also show that between the two catalysts, Pd/c showed a higher activity towards hydrodeoxygenation. Based on the type of components in the produced oil, the maximum fraction of hydrocarbons formed lay within the range of 72.03% and 72.78% green diesel and 30.39 and 28.25% jet fuel using Pd/c and Pt/c catalysts respectively. Thus it can be concluded that waste date pits can be a promising springboard for the production of catalysts and biofuels (green diesel and jet fuel fractions).

A research (Nasser, R. A.-S. (2014). An Evaluation of the Use of Midribs from Common Date Palm Cultivars Grown in Saudi Arabia for Energy Production. BioResources, 9(3), 4343–4357. http s://doi.org/10.15376/biores.9.3.4343-4357) has been conducted to evaluate the potentiality of use of date palm midribs as an alternative source for energy production. Three healthy 10-15 year old date palms of cultivars Barhi, Khalas, Khodry, Sukkaria and Sullaj, grown at the experimental station for Research and Agriculture of King Saud University were chosen for the conduction of this research. Three date palm midribs were randomly selected from the pruning residues. Each midrib was divided into three zones (base, middle and top). The content of ash was calculated as a percentage of the residues based on the oven-dried midrib meal weight. The higher heating value (HHV) was determined using a calorimeter based on the oven-dry weight. The statistical ANOVA analysis has shown that the chemical constituents of the date palm midribs differed significantly between the researched 5 date palm cultivars. The date palm midrib contents of cellulose, hemicellulose and lignin ranging from 42 to 46%, 25 to 30 % and 26 to 31% respectively were found similar to those found in wood species. The lignin content was found to increase moving along the midrib from the base to the top ranging from 24% to 30%. The inverse trend was recorded for the ash content decreasing from 7.6% at the midrib base to 3.4% at the top. Thus it can be concluded that the date palm midribs include higher total extractives (19.34 to 21.68%) and ash content (3.31 to 5,85%) as compared with soft and hard woods. The relatively high heating values found for the date palm midribs (17.3 to 17.9 MJ/kg) prove that they are promising as an energy source. However, the high ash content of all the parts of the date palm midribs, especially the basal part represents a hinderance in their use as a source of fuel.

Besides, the date palm midribs exhibited the lowest fuel value index values (97 to 336) as compared with the corresponding values published in the literature for different wood species.

A research (Sadig, H., Sulaiman, S. A., Zaidi Moni, M. N., & Anbealagan, L. D. (2017). Characterization of date palm frond as a fuel for thermal conversion processes. MATEC Web of Conferences, 131, 01002. https://doi.org/10.1051/matecconf/201713101002) has been conducted to characterize the date palm midrib as a potential solid fuel for jet and power generation through various thermal conversion processes. To conduct this study date palm midribs were sourced from Medina (Rothanah & Ajwah varieties) and Jeddah (Jeddah & Sukkaria varieties) in Saudi Arabia and from Atbara (Mishria variety), North Sudan. These samples were individually prepared to evaluate their fuel properties: ultimate analysis, proximate analysis and calorific value analysis. All the midrib samples gave calorific values ranging from 16.2 to 16.9 MJ/kg and thus falling within the range of biomass materials from 15 to 20 MJ/kg and close to that of low rank coal such as peat and lignite.

Thus it can be confirmed that the date palm midribs enjoy the potentiality of use as a solid fuel for home and industrial applications. As far as the ultimate analysis results are concerned the range of carbon, hydrogen and oxygen in the date palm midribs is comparable with that for typical biomass materials. But the nitrogen and sulfur contents in all samples were found higher than those in most biomasses. The proximate analysis results indicated a significantly high content of volatile matter in the date palm midribs implying their suitability for pyrolysis and gasification processes. Meanwhile, the ash content in the date palm midribs was found comparable with those values in the featured biomasses and lower than in peat, lignite and bitominous coals making the date palm midribs a highly appropriate fuel for continuous thermal processes, where ash removal and handling is a common technical barrier. The thermal decomposition stages were identified based on TGA trends and DTGA peaks. The high reactivity of midrib samples at low temperatures releasing high amounts of volatiles revealed their potentials for pyrolysis and low temperature gasification puroposes. Thus, it can be concluded that the date palm midribs satisfy the typical requirements as a solid fuel for thermal conversion processes in heat and power generation sector. The date palm midribs enjoy the advantages of high availability, low cost and ease of moisture removal in arid and semi-arid regions and thus have high potentials to be used as a solid fuel for thermal applications in the Arab Peninsula and North African countries.

Another research (A. Sulaiman, S., S. Bamufleh, H., N.A. Tamili, S., Inayat, M., & Y. Naz, M. (2017). Characterization of date palm fronds as a fuel for energy production. Bulletin of the Chemical Society of Ethiopia, 30(3), 465. https://doi.org/10.4314/bcse.v30i3.15) was devoted to the study of date palm midribs as an effective feedstock for energy production. To conduct this research date palm midribs of Sukariah, Ajwah and Jeddah varieties were sourced from Madinah Al Munawarah and Jeddah cities in Saudi Arabia. The moisture content, volatile matter, ash and fixed carbon were determined by proximate analysis using Thermogravimetric Analyser (Pyris 1 TGA).

Jeddah had the highest value of volatile matter amounting to 83%, whereas Ajwah had the lowest value of 78.2%. The petiole had the lowest value of volatile matter of 55.3% among the date palm biomass. According to published literature, the date palm midribs values of volatile matter content are comparable with other resources, such as sugar cane bagasse, oil palm midribs and western hemlock. Regarding the heating value Sukariah midribs showed the highest value of 16.8 kJ/kg, whereas Jeddah sample revealed the lowest value of 16.4 kJ/kg compared with the seed value of 18.97 kJ/kg and bituminous coal of 34 kJ/kg. Therefore it can be concluded that the date palm midribs can be used as an alternative feedstock for different energy conversion processes, such as gasification, pyrolysis and torrefaction. The presence of metallic elements can cause problems in the thermo-chemical processing systems and therefore require proper handling and treatment during process.

A study (Makkawi, Y., El Sayed, Y., Salih, M., Nancarrow, P., Banks, S., & Bridgwater, T. (2019).

Fast pyrolysis of date palm (Phoenix dactylifera) waste in a bubbling fluidized bed reactor. Renewable Energy, 143, 719–730. https://doi.org/10.1016/j.renene.2019.05.028) has been devoted to the characterization of three date palm residues: leaves, empty fruit bunches and petioles and their fast pyrolysis in a bubbling fluidized bed reactor at 525 °C. The date palm residues were sourced from the Ameriacn University in Sharjah campus (Sharjah, UAE). The fast pyrolysis experiment was conducted at the European Bioenergy Research Institute in Aston University, Birmingham, UK. The comparison of the proximate and ultimate analysis of the leaves, petioles and empty fruit bunches have shown great similarity, but with the leaves much higher ash was noticed. In comparison with other types of biomass and energy crops, the date palm residues can be classified as of high ash, high oxygen, low volatiles and average heat value. The fast pyrolysis product was found to consist of 38.65% bio oil(including 10.39% reaction water), 37.23% biochar and 24.02% non condensable gas.

The GC-MS analysis revealed for the first time the detailed composition of the date palm pyrolysis oil consisting of at least 140 detectable compounds with the major ones being D-Allose (monosaccharide), phenols, catechol and apocynin. The latter two compounds are of particular interest due to their antioxidation characteristics. The bio-oil heating value was 20.88 MJ/kg, which falls within the low-intermediate range for most fast pyrolysis bio-oils. However the oxygen content was high, and this may have a negative impact on the oil stability and corrosivity. Future work will be directed to the application side of the pyrolysis products including the potentiality of use of bio-oil as a blend with biodiesel for combustion engines, as well as the long-term aging and stability of the bio-oil and potentiality of use of the biochar for soil amendment, especially in desert conditions.

An important study (El may, Y., Jeguirim, M., Dorge, S., Trouvé, G., & Said, R. (2012). Study on the thermal behavior of different date palm residues: Characterization and devolatilization kinetics under inert and oxidative atmospheres. Energy, 44(1), 702–709. https://doi.org/10.1016/j.energy.2012.05.022) has been devoted to the investigation of the thermal behavior of the date palm residues including: leaflets, midribs, trunk, spadix stems and date seeds. These residues have been obtained from a date palm oasis in Tozeur, Tunisia. The ultimate analysis corresponding to the elemental composition of the samples was performed by Service Central d'Analyses (Vernaison, France). The proximate analysis was carried out using a thermogravitmetric analyzer (CAHN121 thermobalance) with gas following upward through the furance at 12NL/h. The thermal behavior of the biomass has been studied under inert and oxidation conditions using a CAHN 121 thermo-balance. The obtained results show that the tested samples have high content of volatiles, carbon, hydrogen and oxygen, whereas the contents of nitrogen and sulfur were relatively low. The researched materials were found to have typical composition as compared with biomass.

The heating values (LHV) were found in the range from 15.2 to 19.0 MJ/kg, which are in the same order of magnitude as those for sawdust, olive solid waste, oil palm fruit bunches, Miscanthus, wood pellets and wood chips. It is interesting to note that among the date palm residues the date palm stones having the highest percentage of volatiles and fixed carbon and the lowest ash content enjoy the highest calorific values in terms of low heating value. The bulk density of date seeds was very high (656 kg/m^3), higher than that of wood chips (550 kg/m^3). The energy density of the date seeds (11.4 GJ/m^3) was found much higher than other date palm residues and approaching that of wood pellets (12 GJ/m^3).

It can be thus concluded that the date palm seeds are the most attractive residue for energy production due to its high energy density and thus low cost of transportation. But the heating values of other date palm residues are high enough to overcome the problems associated with low energy density. Thus, the obtained results can be useful for the design of processing systems for the production of energy from date palm leaflets, midribs, trunks, date stones and spadix stems.

There are strong expectations that the fossil fuels such as oil, coal and natural gas will be depleted within the next 40-50 years. Therefore, there is a growing interest among researchers to study the potentiality of use of biomass for energy production as a more sustainable substitute for fossil fuels, as well as for the rescue of the environment from CO_2 emissions. Therefore, a study (Elmay, Y., Jeguirim, M., Dorge, S., Trouvé, G., & Said, R. (2014). Evaluation of date palm residues combustion in fixed bed laboratory reactor: A comparison with sawdust behaviour.

Renewable Energy, 62, 209–215. https://doi.org/10.1016/j.renene.2013.07.007) has been conducted for the evaluation of date palm residues combustion in a fixed bed laboratory reactor as compared with sawdust behavior.

Samples of Deglet Nour date palm residues were sourced from Djerid region in Tunisia including the leaflets (DPL), rachises (PDR), trunks (DPT), spadix stems (FS) and date stones (DS). The ultimate analyses corresponding to the elemental composition of the date palm residues samples were carried out by Service Central d'Analyses (Vernaison, France) according to the relevant XP CEN/TS15014 standard method. Proximate analysis was conducted using a thermogravimetric analyser (CAHN 121 thermobalance). The high heating values (HHV) were measured following XPCEN/T515103 standard methods using an adiabatic oxygen bomb calorimeter (1KA). The energetic potential for different residues was estimated basing on the calculation of the low heating values, bulk density, energetic density that is the potential of energy per unit of biomass volume.

Referring to the results of ultimate and proximate analyses, the weight fractions of the different date palm residues were found of the same order as several biomasses. The comparison between the date palm residues and conventional biomasses has shown higher chlorine content for PDR, FS and DPT samples with values above 1%. Thus future controls of this element in gas and particles in fumes are needed in order to reduce both corrosion impacts and emission factors of persistent organic pollutants as dioxins and furans. The low heating values (LHV) were found within the range from 15.2 to 19.0 MJ/kg, i.e. in the same order of magnitude as for olive solid waste, Miscanthus, wood pellets and wood chips.

The date stones (DS) were found to have the highest percentage of volatiles (VM) and fixed carbon (FC) and lowest ash content similar to sawdust. The bulk density is an important characteristic of the biomass materials in relation to transport and storage cost. It was found that the bulk density value for DS is very hight (656 kg/m^3) higher than that for wood chips (550 kg/m^3). In addition the energy density (ED) of DS was found 11.4 near to that for wood pellets (12 GJ/kg). Thus it can be concluded that date seeds (DS) is the most attractive material for energy production because of its high energetic density and therefore low cost of transportation. The date seeds is one of the best biofuels enjoying the advantages of highest bulk density, calorific value and volatile matter content and the lowest ash content close to 1.2%. Its energy density (11.4 GJ/m^3) is much higher than other date palm residues. Although the highest value of LHV was obtained for date palm leaflets, their high ash content (15.2%) represents a hinderance for their development as a biofuel since it may lead to corrosion problems in the combustion chambers.

As biofuels the date palm rachis (DPR), date palm trunk (DPT) and spadix stem (FS) have very close energtic density chemical composition. The high amount of chlorine in DPR and DPT may introduce potential risks of corrosion in exchange boiler tubes and the formation of persistent organic pollutants as dioxin during combustion in district or domestic applications.

A study (Elmay, Y., Jeguirim, M., Dorge, S., Trouvé, G., & Said, R. (2014). Evaluation of date palm residues combustion in fixed bed laboratory reactor: A comparison with sawdust behaviour. Renewable Energy, 62, 209–215. https://doi.org/10.1016/j.renene.2013.07.007) has been devoted to the chemical analysis of date palm residues for energy production using ultimate, proximate and thermos-gravimetric techniques: the Sukkari cultivar has been chosen as an important variety cultivated in most areas of Saudi Arabia. The date palm residues were chosen to include palm trunk (PT), palm frond base (petiole)(PFB), palm leaflets (PL), fruit stalk (FS), fruit empty bunch (FEB), date palm stones (DPS) and leaf sheaths fibers (LSF) taking Acacia tortils wood (AT) as a reference. These residues were found to have medium to high cellulose content (33-48%) and lignin (26-40%) and low to medium hemicellulose content (13-31%). The total extractives were (8-33%) and the ash content (1- 15%) (lignin and higher extractive content contribute to a high heating value, whereas ash is considered an undesirable material). The volatile matter content ranged from 74.3% for PL to 87.5% for FEB; fixed carbon ranged from 10.5 for PL to 17.6% for PT and the ash content ranged from 1.4% (DPS) to 15.2 for PL. The heat values of the residues varied from 15.47 MJ/kg for PFB to 19.93 MJ/kg for LSF. However, the heat values based on ash-free dry weight had a wide range from 16.5 MJ/kg for FEB to 22.6 MJ for PL due to the large variation in the ash content (1.3%-11.6%). The fuel value index of DPS was higher (2078) than the value for A.tortilis wood (1170) and other date palm residues. Concerning the ranking of the date palm residues, the date stones (DPS) showed the best value (1.9), followed by leaf sheaths fibers (LSF) (2.5), while the palm frond base (PFB) showed the poorest rating (6.3). Thus it can be concluded that the date palm seeds and leaf sheaths fibers are the most suitable among the date palm residues for energy production.

A research (Mudhafar Kareem Abdullah & A Bulent Koc. (2010). Ultrasound Assisted Oil Extraction from Date Palm Kernels for Biodiesel Production. 2010 Pittsburgh, Pennsylvania, June 20 - June 23, 2010. 2010 Pittsburgh, Pennsylvania, June 20 - June 23, 2010. https://doi.org/10.13031/2013.29928) has been devoted to the ultrasound assisted oil extraction from date palm kernels for biodiesel production.

Three solvent types were used: hexane, isopropyl alcohol and ethanol for oil extraction from date palm kernels and ultrasound was applied for 5 min to 25 min at 5 levels using transesterification of oils with methanol and potassium hydroxide. It was found that the ultrasonic-assisted hexane oil extraction provided the highest yield by extracting 85% of the total available oil present in the date palm kernels. The biodiesel samples produced from oils extracted with and without ultrasonification had similar physical and chemical properties. Thus it can be concluded that ultrasonification has a potential to enchance the industrial processes by reducing the oil extraction time and energy.

A research (Fang, C., Schmidt, J. E., Cybulska, I., Brudecki, G. P., Frankær, C. G., & Thomsen, M. H. (2015). Hydrothermal Pretreatment of Date Palm (Phoenix dactylifera L.) Leaflets and Rachis to Enhance Enzymatic Digestibility and Bioethanol Potential. BioMed Research International, 2015, 1–13. https://doi.org/10.1155/2015/216454) has been devoted to the hydrothermal pretreatment of date palm leaflets and midribs to evaluated their potential for bioethanol production. To conduct this research date palm leaves were sourced from Abu Dhabi in 2013. Leaflets were separated from the midribs, dried and stored before use. The dried material was milled using a knife mill to pass through a 1mm screen, sequential Soxhlet extractions with water and ethanol were performed based on National Renewable Energy Laboratory (NREL) protocol. The hydrothermal pretreatment was performed at 10% w/w dry matter at 4 temperture levels (180, 190, 200 and 210 °C).

Processing time was at 10 min. The research results showed that high glucan (> 90% for both leaflets and midribs) and high xylan (>75% for leaflets and> 79% for midribs) recovery were achieved. Under the optimal conditions of hydrothermal pretreatment (210 °C for 10 min) highly digestible (glucan convertibility 100% to leaflets, 78% to midribs) and fermentable (ethanol yield 96% to leaflets, 80% to midribs) solid fractions were obtained. The fermentability test of liquid fractions proved that no considerable inhibators to saccharomyces cerevisisae were produced in hydrothermal pretreatment. Proceeding from the high sugar recovery, enzymatic digestibility, and ethanol yield it can be concluded that the production of bioethanol by hydrothermal pretreatment from date palm residues is feasible.

A research (Bensidhom, G., Ben Hassen-Trabelsi, A., Alper, K., Sghairoun, M., Zaafouri, K., & Trabelsi, I. (2018). Pyrolysis of Date palm waste in a fixed-bed reactor: Characterization of pyrolytic products. Bioresource Technology, 247, 363–369. https://doi.org/10.1016/j.biortech.2017.09.066) has been conducted on the characterization of pyrolytic products of date palm residues. The pyrolysis process is a thermal cracking of the biomass in an inert atmosphere at temperatures ranging from 300 to 700 °C to produce useful liquid biofuel (bio-oil), solid biocombustible fuel (biochar) and renewable syngas. Therefore, the objective of this study was the investigation of the main characteristics of the obtained products from the pyrolysis of the date pam residues to evaluate their potential as a feedstock for renewable energy and chemical industries.

To conduct this study, four date palm residues samples were obtained from the National Institute of Arid Zone (IRA-Kebili, Tunisia): midribs, leaflets, empty fruit bunches and spathes. The samples were finely crushed to small pieces with sizes from 2 to 4 mm and air-dried. The pyrolysis experiments were conducted on a laboratory scale pyrolysis plant under the operational conditions: 500 °C as final temperature, 15 °C/min and 300g mass initial of the used sample. The elemental composition (CHN-O) of date palm residues, bio-oil and biochar were determined using an elemental analyser (LECOCHNSTRu Spec); the O content was determined by difference.

The proximate and ultimate analyses have shown that the date palm spathes had the least ash content of 2.4%, whereas the leaflets had the highest ash content (11.58%). But in general the date palm researched residues had high volatile matter content and ash fairly compared with those found in the literature for lignocellulosic materials converted into biofuels using pyrolysis.

The calculated high heat values ranged from 17.88 to 19.09 MJ/kg for all studied residues. These values are low for a commercial fuel. The bio-oil yield ranged from 17.03 wt% for leaflets to 25.99 wt% for empty fruit bunches. Concerning the biochar, the highest yield 36.66 wt% was obtained for leaflets, whereas the lowest one (31.66 wt%) was obtained for the spathes, while the syngas production varied from 39.1 wt% for midribs to 46.31 wt% for leaflets. As a conclusion of this study, the bio-oil which represents moderate amounts of carbon and hydrogen compared to petroleum based fuels, could be used as a biofuel after grading. The biochar could be used as biocoke in industrial applications. The presence of CH_4 and H_2 in significant proportions in the gaseous mixture gives the obtained syngas good combustion properties.

A study (Fang, C., Thomsen, M. H., Brudecki, G. P., Cybulska, I., Frankaer, C. G., Bastidas-Oyanedel, J.-R., & Schmidt, J. E. (2015). Seawater as Alternative to Freshwater in Pretreatment of Date Palm Residues for Bioethanol Production in Coastal and/or Arid Areas. ChemSusChem, 8(22), 3823–3831. https://doi.org/10.1002/cssc.201501116) has been conducted to evaluate the technical feasibility of using seawater instead of freshwater in the pretreatment of date palm leaflets for bioethanol production. The lignocellulosic biorefineries are one of the most promising alternatives for fossil oil. But one of the obstacles of proliferation is the excessive utilization of freshwater (1.9-5.9 m^3 water per $m^3$of biofuel), which may be in shortage in arid and semi-arid regions, where the date palms are usually grown.

In this study artificial seawater has been used to replace fully the freshwater in the hydrothermal pretreatment of date palm leaflets to produce bioethanol. The results of this study confirm the feasibility of replacing freshwater with seawater in the hydrothermal pretreatment of date palm leaflets to produce bioethanol. However a lower crystallinity of cellulose has been observed after treatment with seawater rather than freshwater. Pretreatment by using seawater produced slightly lower digestibility of solids (glucan-to-glucose conversion) in enzymatic hydrolysis than pretreatment by using freshwater. But there was no significant difference in the bioethanol yield. Moreover, the fermentability test showed no significant difference in the bioethanol yield between liquids from pretreatment by freshwater and seawater. Thus it can be concluded that seawater could be a promising alternative to freshwater in biorefineries processing lignocellulosic materials.

Within the expected increase of demand on energy for homes, industries and transportation the expected contribution of biofuels will grow from 50 EJ/year in 2012 to more than 160 EJ/year in 2050. The bioethanol is seen as the main biofuel for the future. Within this framework a study (Ahmed, B., Mabrouk, K., Cherif, K., & Boudjemaa, B. (2016). Bioethanol production from date palm fruit waste fermentation using solar energy. African Journal of Biotechnology, 15(30), 1621–1627. https://doi.org/10.5897/AJB2016.15368) has been devoted for the realization of an experimental solar fermenter for the production of bioethanol from date palm waste (DPW). To conduct this study DPW of H chef, Kacien and other varieties of date's scraps of the cattle food were sourced from Algerian Sahara. A batch fermenter was designed and installed to operate effectively by using a solar water heater in order to reduce the cost of the bioethanol generation process. The fermenter was realized within the South Society of Metallic Construction (ECOMES), located in Adrar.

Experimentation was performed during the cold season of the year, the 1st week of January 2015. The results of this study indicate that DPW constitute a favorable medium for S.cerevisiae growth, due to its sugar content and is thus considered as attractive feedstock. It is thus technically feasible to produce bioethanol using the solar batch fermenter at relatively moderate cost. The DPW distilled juice produced the highest bioethanol concentraction of about 90° with an acceptable productivity of 3.47 ml/kg/h assessing a scale efficiency 33%. These results represent a strong support to continue R&D in the renewable energy field. It is thus necessary to start to build semi-pilot and pilot fermenters and investigate new methods, microorganisms and other byproducts to improve the quantity of bioethanol produced and to reduce the energy consumption during the bioethanol process transformation to improve the economics of bioethanol production.

A study (Mukhtar M.Ashur, Salh M.Aldulaimi, Iman M.Bengharbia. (n.d.). Biogas Production from Date Palm Trees Residues. 2019.) has been conducted to explore the anaerobic digestive technology for processing of date palm residues being the most available and sustainable feedstocks for renewable energy. These residues, annually available with huge quantities are most dominantly treated as waste: being open-field burnt or sent to landfills. Therefore the exploitation of these residues for the production of methane gas should be seriously considered. A carbon to nitrogen (C/N) ratio between 20 to 30 is regarded optimum for anaerobic digestion process. To conduct this study midribs, fruit empty bunches and rotten dates were sourced from the southern oases of Libia. In this research two liters batch digester was used. The results of the study have shown that production of biogas from fresh waste nitrogen source (NH_4CI) gives best biogas production compared to dry waste with nitrogen source (NH_4CI) and fresh waste without nitrogen source (NH_4CI). The bio-gas production of dry waste nitrogen source (NH_4CI) was better than biogas production from fresh waste without nitrogen source (NH_4CI). Thus it can be concluded that the heat treatment of date palm residues is very useful to improve the production of biogas. The percentage of methane gas in the produced biogas reached 48% for fresh waste with addition of nitrogen source. The maintenance of pH in the digester at range 6.5- 8 is more efficient to produce biogas. The retention time for fresh waste inside the digester is less than that for dry waste. The palm tree wastes contain a high ratio of carbon compared to nitrogen specially the dry one and addition of nitrogen source is required.

A study (Jaffer KA. (2014). Biogas production by anaerobic digestion of date palm pulp waste. Al-Khwarizmi Eng. J, 5(5), 591– 600.) has been devoted to investigate the usage of date palm biomass for biogas production. The Zahdi date cultivar has been chosen because of its abundance in Iraq representing 60% of the country production. The Waste Management Lab/Corneal University (USA) methodology for anaerobic digestion was used in this research. The results of the study indicate that the volatile solids of substrate and inoculums was 39.82%, 2.37% respectively with a ratio 16.8:1. The nitrogen content of the substrate was found 2.35 indicating the demand for extra amount of nutrients to provide nitrogen for bacteria growth in the fermentation batch. A total gas pressure with 67% Methane was produced from date pulp waste fermentation with a yield of 0.57 Lit for each gram volatile solid of the substrate. The addition of 1% yeast extract solution as a nutrient increased Methane yield in liters by 5.9%. The high volatile solids content in the date palm biomass compared to inoculums indicates a high potential of biogas production from a small amount of biomass. Given the great abundance of date palms in the Middle East and North Africa there are great future potentials for production of biogas and biofuel in a commertial scale.

An important study (Lattieff, F. A. (2016). A study of biogas production from date palm fruit wastes. Journal of Cleaner Production, 139, 1191–1195. https://doi.org/10.1016/j.jclepro.2016.08.139) investigated the production of biogas from date palm fruit wastes by measuring the gas volumetric flow rate directly. Samples of Digal date fruit wastes in their final stage of maturity (with hard texture) were sourced from stores of Diyala province in Iraq. A lab-scale digestion system was used in this research. After the samples were pitted, weighted, mixed with a proper amount of water and placed in the digester, eight mixtures of substrates were divided into two groups. Each group contained 4 samples of substrate having ratios of 0.5, 0.2, 0.15 and 0.1 (w/w). They were subjected to anaerobic digestion at 37 °C for mesophilic and 55 °C for thermophilic conditions. The dischange process of biogas was carried out every 3-5 days and the data was saved on a laptob. Concerning the effect of solid mixing ratio the results of the study showed that under mesophilic temperature of 37 °C, the highest biogas yield was achieved in the case of 0.15 w/w (182 L/kg volatile solid mass), whereas the lowest biogas yield was in the case of 0.5 w/w (84 L/kg volatile solids mass). As far as the effect of recycled digestate is concerned, the research results showed that the use of recycled digestate has improved the production of biogas by 12%.

Thus it can be concluded that the date palm fruit wastes are a suitable source for biogas production and that a mesophilic system is the best option for producing biogas from date wastes. A maximum biogas production of 203L/kg volatile solids was achieved for a solid concentration of 0.15 (w/w), when the substrate was mixed with recycled digestate at 25% of the substrate content.

A study (Shanableh, A., & Radeef, W. (2020). Biogas production from raw and oil-spent date palm seeds mixed with wastewater treatment sludge. Biofuels, 11(6), 707–714. https://doi.org/10.1080/17597269.2017.1398954) has been conducted to evaluate the potential impact of date seeds on biogas production. To conduct this study seeds of Khalas and Khudri cultivars were selected. Oil was extracted from the date seeds using an automatic Soxhlet extractor.

The oil-spent date seeds were recovered from the extractor, dried and then used for biogas production. The primary waste water treatment sludge was sourced from a nearby domestic wastewater treatment plant. The total solids of the primary sludge was adjusted to approximately 2% and stored in a freezer in small containers until use. The volatile solids after total solids adjustment reached 1.64%. The preparation of the date seeds/sludge mixtures was conducted by thawing the frozen sludge from containers, mixing and adding the predetermined date seed quantity and then adjusting the pH if necessary to approximately 7.3. After 14 weeks of incubation the biogas production expressed in terms of the date seed/sludge ratios, were in the *following order:*

10%>7.5%≃5%≃2.5%≃0%>20%>40%. The size of the date seed particles did not significantly affect biogas production. The specific gas production was in the range of 370-390 mlg^{-1} volatile solids for the 0- 10% seed/sludge ratios, 245 mlg^{-1}at 20% and 120 mlg^{-1} for volatile solids at 40%. The relatively low biogas production from the 20 and 40% seed/sludge mixtures indicated inhibation, which was also, shown by the low pH in the mixtures following digestion. Oil extraction from the date seeds reduced, but did not fully overcome, inhibition of biogas production from the 20% and 40% mixtures.

4.10 Date Palm Byproducts in Other Fields of Applications

An important research (Bamufleh, H. S., Alhamed, Y. A., & Daous, M. A. (2013). Furfural from midribs of date-palm trees by sulfuric acid hydrolysis. Industrial Crops and Products, 42, 421–428. https://doi.org/10.1016/j.indcrop.2012.06.008) has been conducted to investigate the feasibility of production of furfural from date palm midribs using a sulfuric acid catalyzed hydrolysis process. In this research the effect of reaction temperature, liquid to solid ratio, acid concentration and reaction time were investigated and their optimum values determined to attain the maximum furfural yield. Furfural and its derivatives are considered as important chemicals due to their various applications. For example furfural alcohol is employed in chemical industry as an additive or solvent in the manufacture of different resins. In addition, furfural is used as a selective solvent for the separation of saturated from unsaturated compounds in petroleum refining, gas oil and diesel fuel industries. In addition, furfural is also used as a fungicide, weedkiller and as a feedstock for the production of tetrahydrofuran.

In most of the date producing countries in the Arab world the products of pruning of date palms (e.g. leaflets, midribs, spadix stems, petioles and leaf sheaths fibers) are being treated as waste. i.e., open field burnt or sent to landfills. This represents a great loss of such an important treasure of locally available renewable resources.

As a response to this situation, an important research (Bendahou, A., Dufresne, A., Kaddami, H., & Habibi, Y. (2007). Isolation and structural characterization of hemicelluloses from palm of Phoenix dactylifera L. Carbohydrate Polymers, 68(3), 601–608.) has been conducted with the objective of isolation and structural characterization of hemicellulose-types polysaccharides from date palm leaflets and midribs. The hemicellulose type polysaccharides were successfully extracted from the leaflets and midribs of the date palms.

The sugar analysis and Nuclear Magnetic Resonance measurements indicate that they belong to xylans family. This may open new potentialities for the economic utilization of date palm products of pruning.

A study (Ramzi, K., Ikhlass, F., & Farouk, M. M. (2010). Study of liquids absorption and retention capacities of new cellulosic materials and sodium cellulose carboxyl methylation prepared from Posidonia. Fibers and Polymers, 11(4), 593–597. https://doi.org/10.1007/s12221-010-0593-x) has been conducted to investigate the potentiality of transforming the date palm midrib into a sizing agent for use in the textile industry as a substitute for expensive commercial products imported from aboard. The date palm midribs were collected from Monastir (Tunisia). To obtain sodium cellulose carboxyl methylate (NaCMC), the cellulose was transformed into alkali cellulose and then etherification agent (monochloroacetic acid) was then introduced. The performance of NaCMCs was then compared to that of the imported commercial product. To conduct yarn sizing 100% cotton yarns were utilized. To evaluate the performance of the sized yarn, the yarn hairiness and the load and elongation at break were measured. Hairiness is defined as the number of fibrils outside the main axis of the yarn. The results of this research prove the potentiality of use of date palm midrib in the manufacture of sizing materials for yarn as a substitute for expensive imported commercial products.

A research has been conducted with the purpose of extracting cellulose fibers from date palm petioles. The date palm petioles were collected in Monastir, Tunisia. The samples were air-dried, milled and sieved to a grain size between 200μm and 1mm. The extraction of fibers was conducted under alkaline conditions to remove hemicellulose and break the hydrogen bonds and the hydrolyzed ester groups. The chemical composition of the date palm petioles was determined and found: 1,4% extractives, 27.5%

lignin and 67.7% holocellhouse. In this work it was possible to extract and purify cellulose fibers from date palm petioles with a yield of 42%.

Moreover the solubility of cellulose in ionic liquid (N-buthyl-N-methylpyrrolidium-buthyl-dibutthyl thylphosphate) allowed the dissolving of 11g of cellulose per 100g of this ionic liquid at 80 °C. The results of this study provide an environment-friendly method of dissolving cellulose from date palm petioles. It also represents an eloquent example of valorization of date palm products of pruning generally treated as waste.

A research (Musaed N. J. Alawad, Khaled Elshreef, & Ahmed Algobany. (2018, November). Innovative Wellbore Strengthening Using Crushed Date Palm Seeds and Shredded Waste Car Tyres. The 10th ISRM International Asian Rock Mechanics SymposiumAt: Singapore.) has been conducted to evaluate the potentiality of use of date palm seeds powder in sealing of fractures in oil wells. The expenses of drilling of oil wells represent 25% of the total oilfield exploitation cost. The drilling fluids represent 15 to 18% of the total cost of petroleum well drilling operations.

One of the problems in well drilling is the loss of drilling liquids into drilling-induced fractures or natural fractures in wells. Therefore, it is necessary to find appropriate materials that can efficiently seal these fractures during drilling operations. In this research two superior fracture seal materials made from crushed date palm seeds and shredded waste tyres were tested in laboratory conditions to seal artificially fractured holes under high temperature and pressure conditions. Mixtures of either crushed date palm seeds or shredded waste car tyres of different grain sizes proved its ability to completely seal the samples at pressures up to 1000 psi and temperature up to 90 °C. In addition to its superior ability to seal the fractured formations, the date palm seeds are cheap, locally available in commercial quantities, environmentally friendly and easy to crush into various required grain sizes.

A research (Elwaleed, A. K., Nikabdullah, N., Nor, M. J. M., Tahir, M. F. M., & Zulkifli, R. (2013). Experimental investigation of sound absorption properties of perforated date palm fibers panel. IOP Conference Series: Materials Science and Engineering, 46, 012027. https://doi.org/10.1088/1757-899X/46/1/012027)has been conducted to study the effect of using a perforated plate on the sound absorption of date palm leaf sheaths fibers. To conduct this research, fibers were collected from the sheathing leaf bases and dried in shade at room temperature for 2 days. The pulp (paranchyma) was removed from fibers by combing and the fibers were then scrapped to remove the pulp completely. The average diameter and density of the fibers were 0.408 mm and 919 kg/m^3 respectively. The plastic molds were fabricated with diameters 28 mm and 100mm to suit the two impedance tubes used in this research. The thickness and density of prepared samples were 30 mm and 77 kg/m^3 respectively. The frequency span of the experiment was 100-5000 Hz with 3 Hz resolution. An aluminum performed plate was used to enhance the sound absorption. The experiment was conducted for the panel without air gap, with air gap of 10,20 and 30 mm between the date palm fiber sample and the rigid backing of the impedance tube. The use of the perforated plate has led to the increase of the absorption coefficient between 1000 Hz and 3000 Hz by shifting the peak toward the low frequency range.

However, the sound absorption coefficient decreased above 3000 Hz and the peak decreased by 4%. The results show that the best performance for improving the sound absorption at low frequency range can be achieved using the date palm leaf sheaths fibers combined with the perforated plate facing and the 10 mm air gap backing. The performance of the date fibers can be improved by increasing the samples density and using plates with different perforations.

V. THE DATE PALM AS A SPRINGBOARD FOR CIRCULAR BIOECONOMY: A BIOREFINERY FOR EACH DATE PALM BYPRODUCT

This chapter proceeds from the reality of each date palm plantation with its production: of dates and byproducts that can be sorted in site to different byproducts and from the necessity of rational utilization of these byproducts.

Otherwise, these byproducts will turn into waste (as the situation is most predominantly now) being either open-field burnt causing considerable environmental pollution or sent to landfills!

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Designing the Global System for Mobile Communications "GSM-900" Cellular Network Up to the Nominal Cell Plan in Tripoli, Libya

Ali Othman Albaji, Abdelnaser Omran, Rozeha A, Rashid, Yaseen Hadi Ali, Abdusalama Daho & Ali Hakami

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ABSTRACT

The construction and design of cellular networks are complex processes. They involve the selection of the necessary components and the allocation of support infrastructure. In this study, we introduce an integer programming model that can help network designers maximize their net revenue. The model takes into consideration various factors such as the cost of running a business, the bandwidth available, and the customer area's revenue potential. It also takes into account the sizes and locations of each cell.

This research provides a variety of solutions for designing and building cellular networks. This study takes into account the various factors that affect the design and construction of cellular networks. It also takes into account the channel sizes and locations of each cell. It is specific research and given the spectrum (20 MHz), channel bandwidth (200 kHz), and C/I = The minimum operating C/I of 15 dB, a spectrum 20MHz and full-duplex channel bandwidth is 200KHz. The various components of a network's startup point, such as the network type, multiple access protocols, and control principles, are based on the frequency band for reuse and the table-building process. The cell planning process is based on the code division and frequency division of the GSM frequencies. In code division cases, the users and base stations of the same network are separated by codes.

Keywords: cellular networks, complex processes, bandwidth, cell planning, GSM.

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The construction and design of cellular networks are complex processes. They involve the selection of the necessary components and the allocation of support infrastructure. In this study, we introduce an integer programming model that can help network designers maximize their net revenue. The model takes into consideration various factors such as the cost of running a business, the bandwidth available, and the customer area's revenue potential. It also takes into account the sizes and locations of each cell.

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Keywords: cellular networks, complex processes, bandwidth, cell planning, GSM.

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I. INTRODUCTION

The development of the cellular concept was largely due to the need to address the issue of user capacity and spectral congestion. It allowed for the use of a lot of spectrums without requiring major technical changes. Instead of a single high-power transmitter, a series of low-power ones are used to cover a specific area within the service area of the cellular concept [1][2]. A base station's position is assigned various sets of channels, which then result in a small number of stations being able to access all of them. By separating the channels, the interference between the base stations and the cellular users is lessened. In this research, we provided the solution for the cellular GSM network in Tripoli city. There will include all stages of GSM mobile network design, but up to the "nominal cell plan", because after that, there should start work for territory surveys, radio propagation/coverage simulation/calculation, final cell plan (final design) implementation, and so on. The listed,

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what should go after “nominal cell plan”, does not include in our research, it is the other level in design. Tripoli city has an area of 1507 square kilometres with a population of 3 million. The network should have at least an operating C/I of 15 dB, spectrum 20MHz, and full-duplex channel bandwidth 200KHz. The network will base on GSM, and stations (St,S) will run in the 900 MHz diapason, which will be parcelled out into 2 scopes of 20 MHz (each canal 200 kHz), for downstream to the mobile St (BS to MS) make use of 890 to 910 MHz, for upstream to base St (MS to BS) apply 935 MHz - 955 MHz First, we will define the network boundaries and area map, then the work will go through the below steps:

- For the omnidirectional case will build our clusters by determining the spectrum length and bandwidth for each channel, will write about co-channel interference and co-channel tiers in a hexagonal cellular system, will calculate cluster size, will build clusters topology, and determine/find the positions of co-channel cells. Then will apply it to the directional radio propagation case.
- Build a frequencies table, and calculate cell size in the sites, capacity, and BTS count.
- Carry out financial calculations.
- Draw a nominal cell plan

Before starting we need to draw the zone’s border where we should be deployed our network as shown in (Figure 1) below.

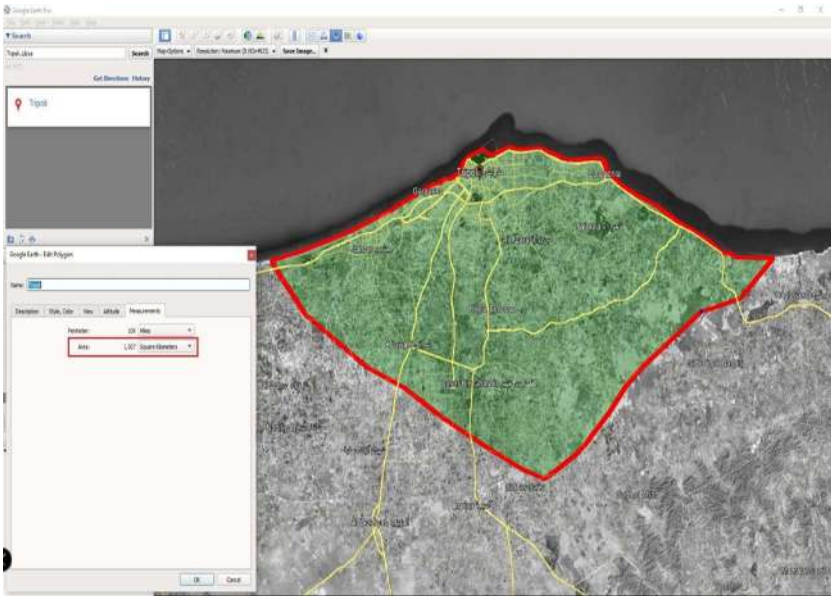


Figure 1: Tripoli, Network’s Zone Border

We can take into account – The GSM 900 cellular network is the best and relatively low-cost basement for starting to deploy the cellular network, it provides necessary services, and so on. And if, in the future, will need to provide more speed mobile data for, for example, for Internet, this infrastructure will allow relatively easy deployment of the LTE/4G/5G network.” One of the costliest components of constructing a cellular network is frequency planning. The cost of deploying and maintaining the network will go down if a group of base stations can be put up with the least amount of preparation and servicing. Planning and optimization are carried out to guarantee that the precious frequency is used as efficiently as possible. Additionally, this is done to guarantee low to no co-channelling interference and excellent efficiency in cellular radio networks. The goal of this research is to develop an automated method for scheduling and maximizing frequency in the cellular network and building the nominal cell plan for the Global System for Mobile Communications "GSM-900" cellular network in Tripoli, Libya. The method substitutes the time-consuming, laborious, and wasteful manual method. Radiofrequency (RF) engineers' work is made easier and less expensive with the automatic method. The automatic method streamlines tasks for radio frequency (RF) engineers and lowers operating costs. The automatic method makes certain that the cellular network is widely implemented in a way that the requirements of maximum quality, quantity, and high coverage are met. One of the goals of the study is to develop an automatic planning and optimization technique that reduces intra-system interference levels to acceptable ranges while maintaining the key performance indicators (KPIs) set for any suitable cellular network [11].

The GSM cellular network is the best and relatively low-cost basement for starting to deploy a cellular network, it provides necessary low-cost calling services for customers, and so on. And if, in the future, will need to provide more than GSM mobile data speed, this existing infrastructure will allow relatively easy deploy the LTE/4G/5G/6G network. It is better for Tripoli to start to deploy the GSM network, provide relatively low-cost services, and then, as and when required, start to realize the, for example, the 5G/6G (LTE) network.

II. CLUSTERS

The cluster consists of sites and cells, i.e., with different working frequencies (in the same frequency range) all sites/cells are grouped in a cluster. First, the necessary calculations for building our cluster will be based on omnidirectional radio propagation. In this case, the “site” and “cell” is the same area/zone. The next stage is applying directional radio propagation conception. It is important for having better C/I and decreasing interference in co-channel cells, reducing the noise level, increasing capacity, and enhancing frequency reuse. Here the cluster will build from “sites” where each "site" consists of a few “cells”.

III. CHANNEL BANDWIDTH AND SPECTRUM LENGTH, FREQUENCY RANGE

The GSM-900 stations are working in the 900 MHz frequency range, which is parcelling out into 2 scopes of 20 MHz (for each channel provided 200 kHz):

- For downstream to the mobile St (BS to MS) using from 890 to 910 MHz
- For upstream to base St (MS to BS) applying 935 MHz - 955 MHz

In GSM for cluster planning, duplex gear, and multiple accesses using the Frequency Division (FD) and Time Division (TD) [1]. Figure 2 and Figure 3) show the duplex distance for the 900 MHz band is 45 MHz [2].

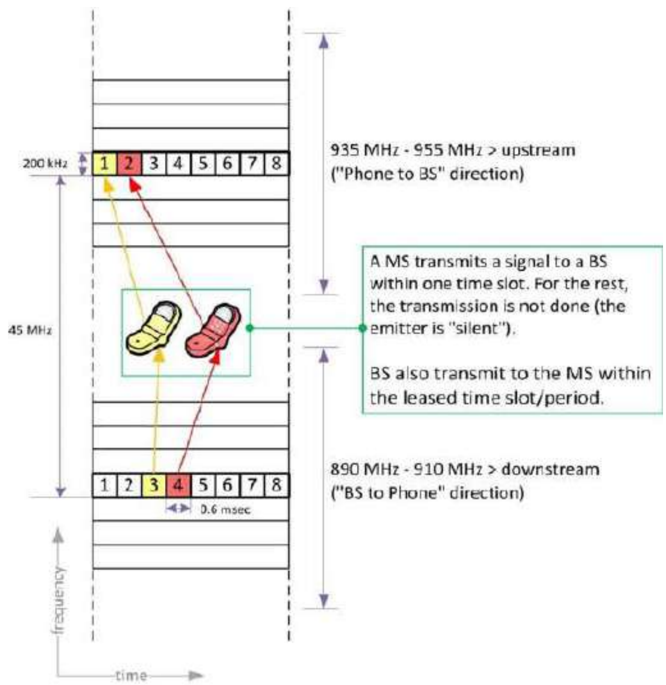


Figure 2: Frequency Division (FD) And Time Division (TD) In Gsm

Within each frequency channel, the data is transmitted across 8-time slots, i.e., each carrier can have 8 connections (Using TD). Eight-time slots are combined in a frame, and 26 frames in a repeater cycle.

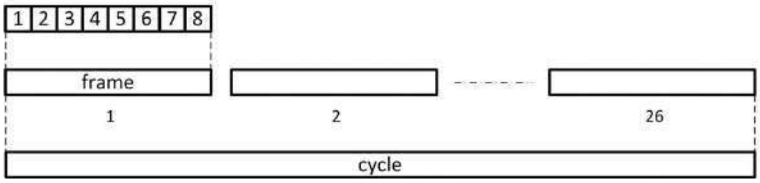


Figure 3: Time Division (Td) In Gsm

VI. CO-CHANNEL INTERFERENCE. HEXAGONAL CELLULAR SYSTEM AND CO-CHANNEL

In the design and building process of cellular systems, there is except radio coverage exists as no less important goal. It is to provide needful capacity.

To increase the capacity of the system, the first step that should be done is frequency reuse. But for each BS there are interferences from stations with the same channel (co-channel interference) and from adjacent frequency channels too. The recommended co-channel interference rate (C/I) and adjacent frequencies interference rate (C/A) [3] are:

- C/I ≥ 9 dB; + additional 3 dB (allowance in engineering) C/I ≥ 12 dB
- C/A ≥ -9 dB; + additional 3 dB C/A ≥ -6 dB

In our research the minimum operating C/I equals 15 dB (in the 1 tier), i.e., must have a C/I ≥ 15 dB value.

For a clear understanding, what is the C/I (carrier to interference rate) in Figure 4 provide the visualization, *where:*

D – Distance between co-channel's sites/cells
R – Radius of observed (main) site/cell

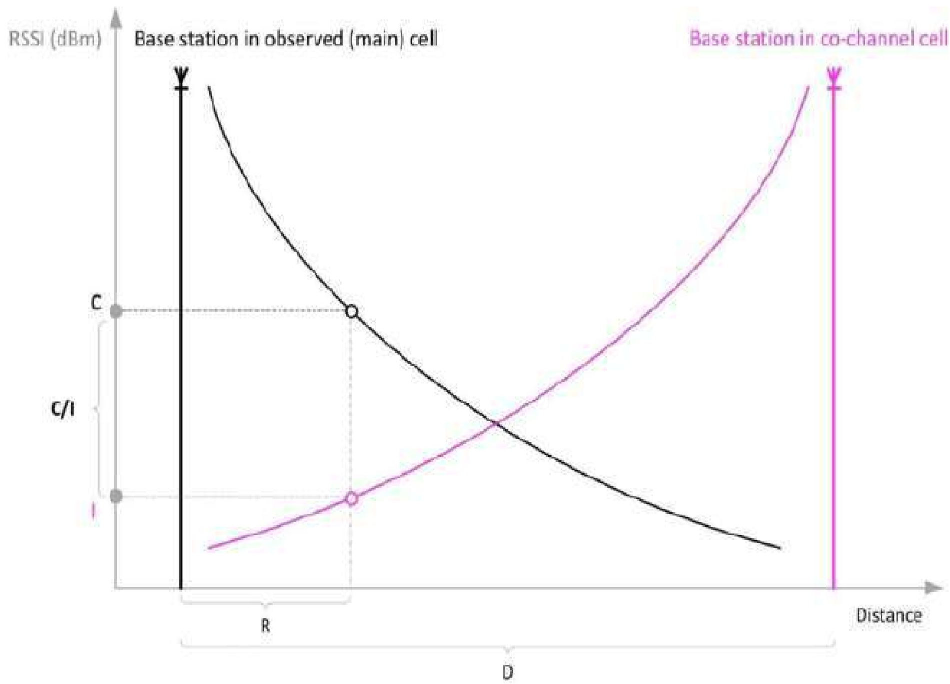


Figure 4: C/I (Carrier-To-Interference Rate) Visualization

To reduce interference, the neighbourhood sites'(cells') working channels are not the same. Sites/cells with different frequencies (with different working channels) are grouped in a cluster. In hexagonal architectures, each "n" tier contains "6 x n" co-channel sites/cells [4]. I.e., on the first-tier as the source of interference are six (6 x 1 =6) co-channel sites/cells, on the second-tier – 12, and so on as can be seen in (Figure 5).

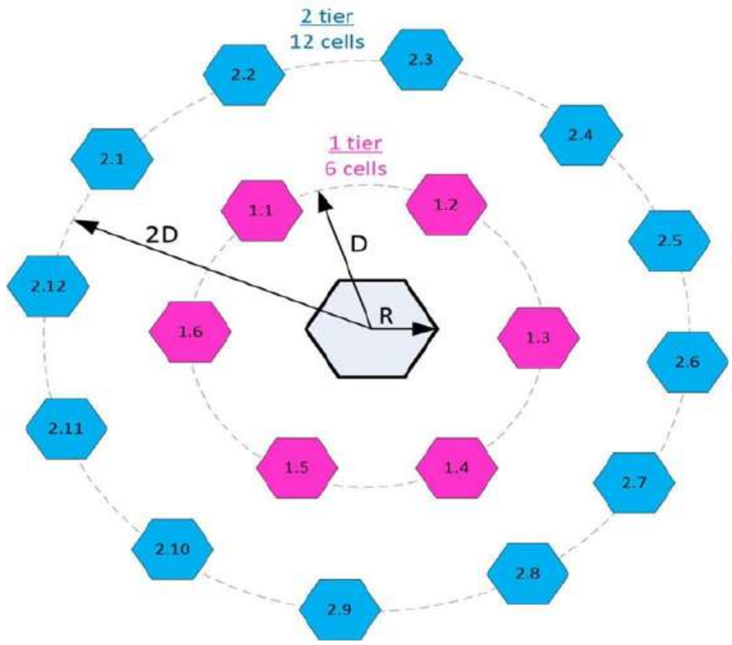


Figure 5: Co-Channel Tiers In Hexagonal Cellular System

Interference analysis is provided in "2.2 co-channel interference. hexagonal cellular system and co-channel tiers". it is provided because in the task wrote – "minimum operating c/i of 15db", so, c/i is a "carrier to interference rate", and must provide this information. also, c/i used in the, for example, for cluster size calculation (2.3 cluster size calculation). By decreasing the transmission power, interference may be avoided. Co-channel interference can be decreased in a cellular structure by substituting only channels. One directional antenna is surrounded by several directional projections at the base station, each emitting within a defined range and industry [12].

V. CLUSTER SIZE CALCULATION

Wherever It may seem the best way to decrease the interference is to increase the transmitter's power. More power may be increasing the C/I for this site/cell, but for the co-channel site/cell doing the opposite effect. The cluster size is based on C/I necessary rate and depends on the D and R values as illustrated in (Figure 4, and Figure 5) [5].

$$\frac{D}{R} = \sqrt{3 \times N}$$

Equation 1: | Co-Channel Reuse Ratio

N – It is a count of sites/cells in the cluster, in other words, it is the cluster size. After calculating the cluster size, the following formula shows the cluster size value[4].

$$\frac{C}{I} = \frac{\left(\frac{D}{R}\right)^{\alpha}}{6}$$

Equation 2: | C/I On R Distance

In our research, the minimum C/I = 15 dB = 31.6228 [6]. Based on the value of α which is known as a path-loss exponent, it can take the below values as shown in Table 1 [7]:

Table 1: Path-Loss Exponent Value

Environment	Path-Loss exponent, α
Free space	2
Urban area cellular	2.7 to 3.5
Shadowed urban cellular	3 to 5
In building LoS	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

So, in our case, α = 2.7 to 3.5, we choose the "3.5" value.

$$\frac{C}{I} = \frac{\left(\frac{D}{R}\right)^{3.5}}{6} \quad \text{and} \quad \frac{D}{R} = \left(\frac{6 \times C}{I}\right)^{1/3.5}$$

As selected above $\frac{??}{R} = \sqrt{3 \times ??}$

By using the above formulas and after calculations, the findings were as the *following:*

$$N = \frac{1}{3} \times \left(\frac{6 \times C}{I}\right)^{2/3.5}$$

$$N = \frac{1}{3} \times (6 \times 31.6228)^{0.57} = \frac{1}{3} \times 189.7368^{0.57} = \frac{1}{3} \times 19.886$$

$$N = 6.629$$

Equation 3: |Cluster Size Calculation - Part2

N can be 3, 7, or 12 [8]

Our cluster should be having a minimum of 7 sites/cells. Our choice is N=7. N=7 cluster example in Figure 6.

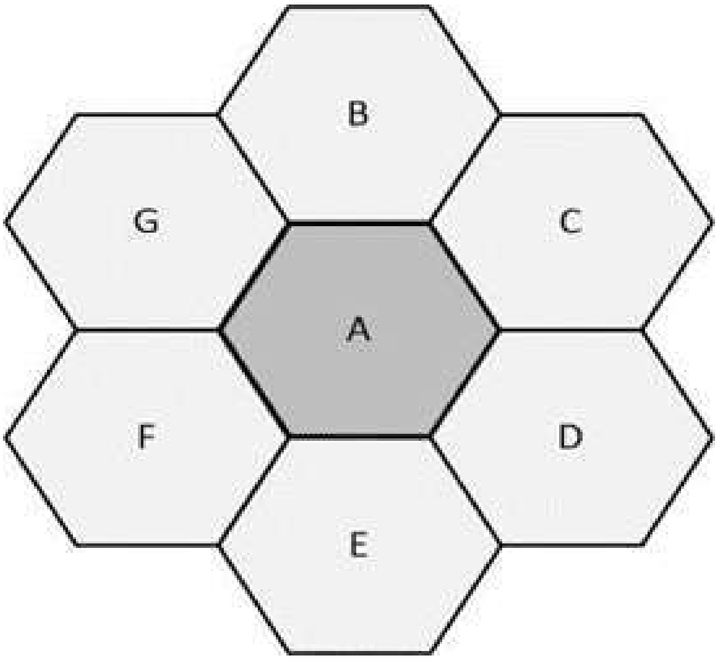


Figure 6: Cluster Cell

A, B, C, ..., G are sites/cells in the same cluster which use different frequencies in the same range, for example for downstream, in the 890 – 910 MHz So, we can use the whole 20MHz in one cluster and reuse the same frequency many times in other clusters as can be seen in (Figure 7).

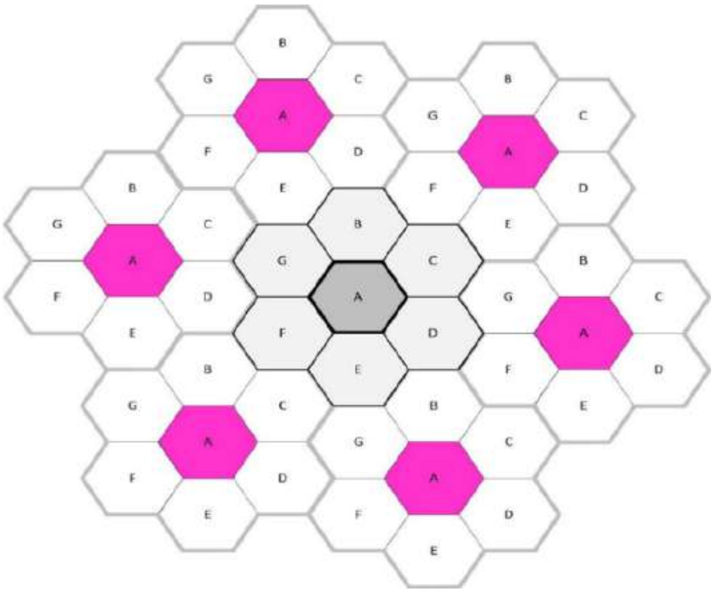


Figure 7: Example of Observed Cluster and His Nearest Six Clusters

IV. CLUSTERS TOPOLOGY (THE CO-CHANNEL CELLS POSITIONS)

The network should provide the required capacity and radio coverage. The cluster will have 7 sites/cells. With additional clusters, we will increase our cellular network if one cluster is not enough to cover the required zone. Our cell and co-channel 6 cells disposition (on tier 1) preview as shown in Figure 8.

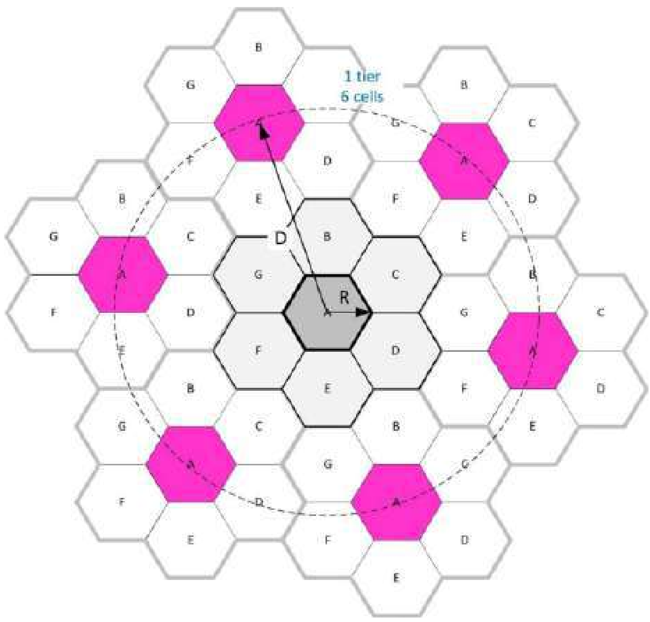


Figure 8: Our Cell and Co-Channel 6 Cells Disposition (Tier 1)

When we design and build the cellular network, we must determine the positions of the co-channel cells in the "surround" clusters (tier1). Where are they should be? Are they in the center of the cluster, or near the border of clusters?

To find necessary positions we should from our observed site/cell count "i" cells in any direction, then rotate 60° counterclockwise and continue moving forward at "j" cells – as shown in Figure 9.

"i" and "j" values depend on cluster size ("N") [4].

$$D = \sqrt{(i^2 + i \times j + j^2)} \times (R \times \sqrt{3})$$

Equation 4: | The Distance Between Co-Channel Sites/Cells

We know that $\frac{D}{R} = \sqrt{3 \times N}$

So, the "N" value can preview as in Equation 5 (Tipper, n.d., p. 7) [8].

$$N = i^2 + i \times j + j^2$$

Equation 4: | "N" Value Via "I" And "J"

In our case N=7, so, we have N=7 (i=2, j=1).

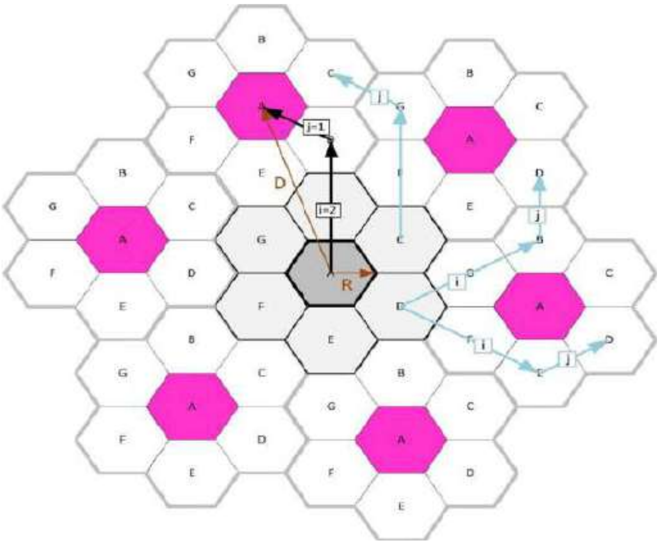


Figure 9: Co-Channel Cells Position Calculation

IIV. SECTORS IN RADIO PROPAGATION (CHANGING TO DIRECTIONAL RADIO PROPAGATION)

Base Station Systems (BSS) provides access to services for mobile customers. Each BSS consists of Base Station Controller (BSC) and Base Transceiver Station (BTS). BTS - includes radio devices (transceiver, receiver, etc.) and antennas. BSC - manages the BTS and the whole radio network [2]. Co-channel cells' quantity and positions, when each BTS used an omnidirectional antenna and via one antenna to cover 3600, were previewed before. The next step is splitting the 3600 directions into 3 directions (1200 sectoring). What will we have?

- Better C/I, reducing interfering co-channel cells quantity (Tipper, n.d., p. 17) [8] as shown in (Figure 10);
- Directional antennas reducing noise level;
- It is increasing capacity, and enhancing frequency reuse.

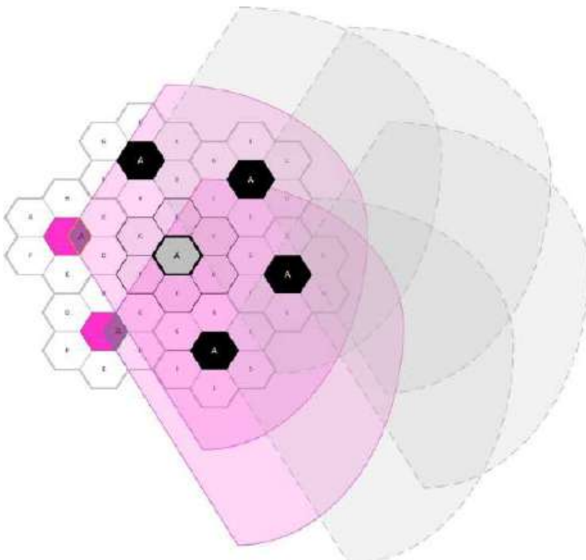


Figure 10: Sectoring – Interfering Co-Channel Cells Quantity To 2

IIIV. THE CLUSTERS TOPOLOGY IN SECTORING RADIO PROPAGATION

In sectoring, radio propagation applied another method for building the clusters. We will divide the sites into three zones where each zone is the cell. In omnidirectional radio propagation, the “site” and “cell” is the same area/zone. In directional radio propagation, the cluster will build from “sites” where each "site" consists of three “cells” as illustrated in (Figure 11).

The BTS was placed on the junction point of three cells. Each cell provides 1200 covering by the directional antenna and each cell will use its frequencies. For example, in the “A” site they are A1, A2, and A3 (Figure 11).

The cluster we will present with the pattern’s notation X/Y.

X – sites count in the cluster.
Y – cells count in the cluster.

The cluster size has already been calculated. Our cluster consists of 7 sites, i.e., have a 7/21 pattern.

It means that the cluster will have 7 sites which will cover 21 zones [2].

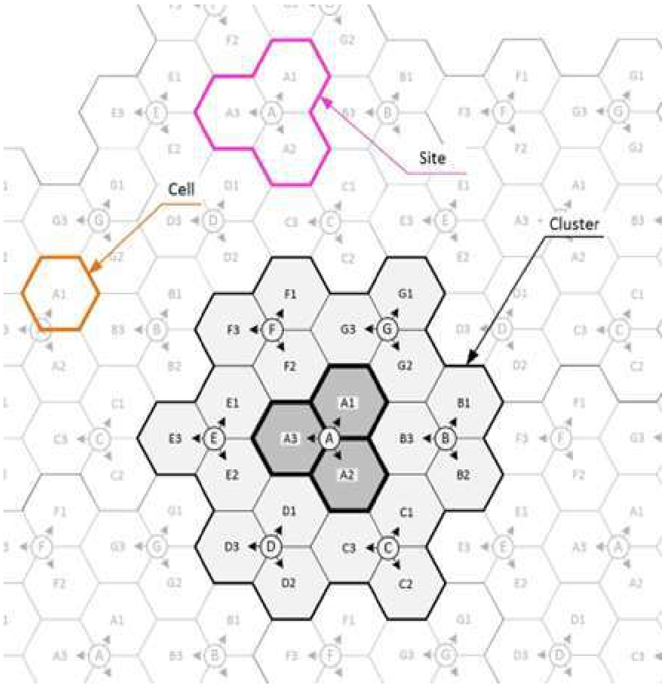


Figure 11: Clusters In Sectoring Radio Propagation

IX. FREQUENCY RANGE, COUNT F CHANNELS

In Part, the BTS to MS uses frequencies from 890 MHz to 910 MHz, for MS to BTS from 935 MHz to 955 MHz and for each direction, we have 20 MHz spectrum, for each channel 200 kHz. So, we will have 20 MHz/200 kHz = 100 channels (100 carriers) for duplex links in each cluster.

As we draw in Figure 2 above, each carrier provided multiple accesses and 8 connection channels per carrier. So, our capacity for each cluster is 8 x 100 = 800 connections, i.e., 800 calls possibility in a zone covered by one cluster.

The cluster will have a 7/21 pattern, 100 carriers/800 connections per cluster. Take into account that the subscribers’ load is uniformly distributed in the cluster, so, in the cluster, we will have for 16 cells the 5 carriers/40 connections per cell, for the remaining 5 cells the 4 carriers/32 connections per cell.

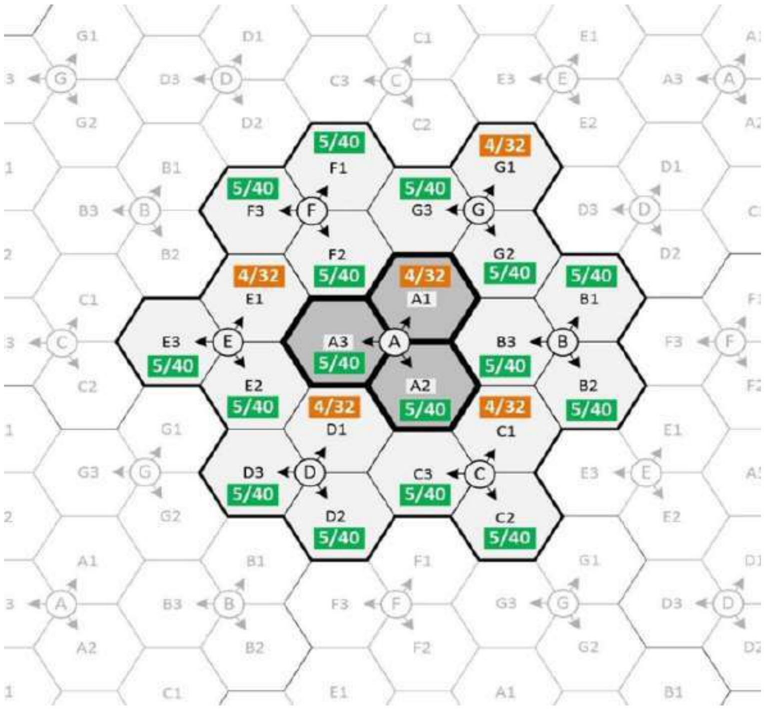


Figure 12: Carriers/Channels In The Cells

In the real network, depending on some situations, for example, depending on subscribers' loads, one cell maybe will need more channels, another one has fewer channels, etc. So, when will need it, we can "withdraw" channels from one cell to another one. Table 2 below shows the frequencies channels values.

Table 2: Frequencies. Channels List

Cell	carriers / connections	BS-MS/MS-BS MHz	Channel Carrier	BS-MS/MS-BS MHz	Channel Carrier	BS-MS/MS-BS MHz	Cell	carriers/ connections	BS-MS/MS-BS MHz
A1	4/32	890/935	Ch 1	890/935	Ch 51	900/945	E1	4/32	890.8/935.8
		894.2/939.2	Ch 2	890.2/935.2	Ch 52	900.2/945.2			895/940
		898.4/943.4	Ch 3	890.4/935.4	Ch 53	900.4/945.4			899.2/944.2
		902.6/947.6	Ch 4	890.6/935.6	Ch 54	900.6/945.6			903.4/948.4
A2	5/40	891.4/936.4	Ch 5	890.8/935.8	Ch 55	900.8/945.8	E2	5/40	892.2/937.2
		895.6/940.6	Ch 6	891/936	Ch 56	901/946			896.4/941.4
		899.8/944.8	Ch 7	891.2/936.2	Ch 57	901.2/946.2			900.6/945.6
		904/949	Ch 8	891.4/936.4	Ch 58	901.4/946.4			904.8/949.8
		908.2/953.2	Ch 9	891.6/936.6	Ch 59	901.6/946.6			909/954
A3	5/40	892.8/937.8	Ch 10	891.8/936.8	Ch 60	901.8/946.8	E3	5/40	893.6/938.6
		897/942	Ch 11	892/937	Ch 61	902/947			897.8/942.8
		901.2/946.2	Ch 12	892.2/937.2	Ch 62	902.2/947.2			902/947
		905.4/950.4	Ch 13	892.4/937.4	Ch 63	902.4/947.4			906.2/951.2
		909.6/954.6	Ch 14	892.6/937.6	Ch 64	902.6/947.6			907.4/952.4
B1	5/40	890.2/935.2	Ch 15	892.8/937.8	Ch 65	902.8/947.8	F1	5/40	891/936
		894.4/939.4	Ch 16	893/938	Ch 66	903/948			895.2/940.2

		898.6/943.6
		902.8/947.8
		907/952
B2	5/40	891.6/936.6
		895.8/940.8
		900/945
		904.2/949.2
		908.4/953.4
B3	5/40	893/938
		897.2/942.2
		901.4/946.4
		905.6/950.6
		909.8/954.8
C1	4/32	890.4/935.4
		894.6/939.6
		898.8/943.8
		903/948
C2	5/40	891.8/936.8
		896/941
		900.2/945.2
		904.4/949.4
		908.6/953.6
C3	5/40	893.2/938.2
		897.4/942.4
		901.6/946.6
		905.8/950.8
		906.8/951.8
D1	4/32	890.6/935.6
		894.8/939.8
		899/944
		903.2/948.2
D2	5/40	892/937
		896.2/941.2
		900.4/945.4
		904.6/949.6
		908.8/953.8
D3	5/40	893.4/938.4
		897.6/942.6

Ch 17	893.2/938.2
Ch 18	893.4/938.4
Ch 19	893.6/938.6
Ch 20	893.8/938.8
Ch 21	894/939
Ch 22	894.2/939.2
Ch 23	894.4/939.4
Ch 24	894.6/939.6
Ch 25	894.8/939.8
Ch 26	896/940
Ch 27	895.2/940.2
Ch 28	895.4/940.4
Ch 29	895.6/940.6
Ch 30	895.8/940.8
Ch 31	896/941
Ch 32	896.2/941.2
Ch 33	896.4/941.4
Ch 34	896.6/941.6
Ch 35	896.8/941.8
Ch 36	897/942
Ch 37	897.2/942.2
Ch 38	897.4/942.4
Ch 39	897.6/942.6
Ch 40	897.8/942.8
Ch 41	898/943
Ch 42	898.2/943.2
Ch 43	898.4/943.4
Ch 44	898.6/943.6
Ch 45	898.8/943.8
Ch 46	899/944
Ch 47	899.2/944.2
Ch 48	899.4/944.4
Ch 49	899.6/944.6
Ch 50	899.8/944.8

Ch 67	903.2/948.2
Ch 68	903.4/948.4
Ch 69	903.6/948.6
Ch 70	903.8/948.8
Ch 71	904/949
Ch 72	904.2/949.2
Ch 73	904.4/949.4
Ch 74	904.6/949.6
Ch 75	904.8/949.8
Ch 76	905/950
Ch 77	905.2/950.2
Ch 78	905.4/950.4
Ch 79	905.6/950.6
Ch 80	905.8/950.8
Ch 81	906/951
Ch 82	906.2/951.2
Ch 83	906.4/951.4
Ch 84	906.6/951.6
Ch 85	906.8/951.8
Ch 86	907/952
Ch 87	907.2/952.2
Ch 88	907.4/952.4
Ch 89	907.6/952.6
Ch 90	907.8/952.8
Ch 91	908/953
Ch 92	908.2/953.2
Ch 93	908.4/953.4
Ch 94	908.6/953.6
Ch 95	908.8/953.8
Ch 96	909/954
Ch 97	909.2/954.2
Ch 98	909.4/954.4
Ch 99	909.6/954.6
Ch 100	909.8/954.8

		899.4/944.4
		903.6/948.6
		907.8/952.8
F2	5/40	892.4/937.4
		896.6/941.6
		900.8/945.8
		905/950
		909.2/954.2
F3	5/40	893.8/938.8
		898/943
		902.2/947.2
		906.4/951.4
		907.6/952.6
G1	4/32	891.2/936.2
		895.4/940.4
		899.6/944.6
		903.8/948.8
G2	5/40	892.6/937.6
		896.8/941.8
		901/946
		905.2/950.2
		909.4/954.4
G3	5/40	894/939
		898.2/943.2
		902.4/947.4
		906.6/951.6
		908/953

X. CELL SIZE

The traffic intensity also can vary depending on the area. It is clear, that in this case, the cell can have different sizes. In high traffic cases, in a region are placed the small cells. When traffic is low, large cells are placed. Figure 13 provided the selected example of this situation by Ericsson (Ericsson - Student Text En/Lzt 123 3314 R3a, 1998) [2].

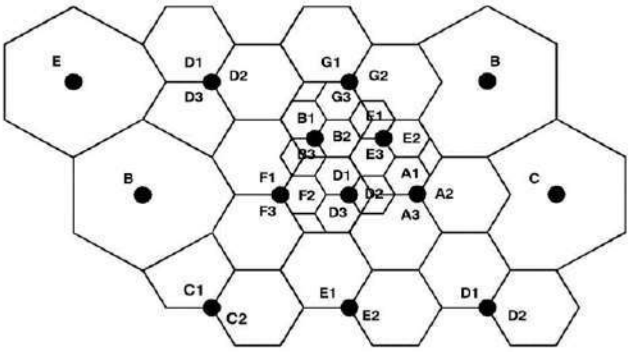


Figure 13: Cells Of Different Sizes

In addition to radio coverage calculation, to determine the radius of the cell (R), the following data are analysed:

A. Roads and highways' direction and congestion:

- The subscriber load's density;
- Capacity requirements.

B. Cells by size qualified as [1]:

- "MACRO" cell (up to 35 km);
- "MICRO" cell (up to 2 km);
- "PICO" cell (up to 100 m).

The small cells provide more capacity, but cars and any other object moving at high speed will frequently jump from one cell's BTS to another one BTS. When clusters build big cells, the other problem will become, that the total capacity will be lower. Thus, the topology of the BTS should be adapted to the value, density, and territorial distribution of the subscriber loads.

10.1 Zone of Transition

If the clusters have different sizes of cells, it provides problems in channel planning because the distance D is will be different for cells with different sizes. The small cells are interfering with the large cell. So, there must be a buffer zone where the small and big cells must not use the same frequencies. If we will use all frequencies in our cluster, we will not have a reserve for buffer zones, and will not have a reserve for additional BTS for future installation also. Additional BTS will need if will need to increase capacity in the existing cluster. So, for cells we will not use all available channels/carriers, we can use some channels as per (Table 2) and not use and reserve those for the future. For example, we can from 5 carriers/40 connections (5/40) as illustrated above in (Figure 12, Table 2) which does not use some carriers (channels) and reserve those for the future. Otherwise, to increase the capacity, we should do our cells small, which will decrease cluster size and we should be building additional clusters to cover our network's area.

10.2 Grade of Service (Gos)

Cellular network capacity depends on the count of the available channel and grade of service (GoS). The probability of blocking calls (GoS) is the percentage of failed attempts to set up a connection due to network congestion. To simplify cell capacity calculations, the results of the calculations are usually given in the form of an Erlang B table [2], as explained in (Table 3) below. Rows (n) – number of traffic channel Columns (GoS) – a function of the GoS acceptable value is 2% [2]. As per Table 3 extraction, it is found to be 2% = .02.

Table 3: Erlang B Table

n	.007	.008	.009	.01	.02	.03	.05	.1	.2	.4	n
1	.00705	.00806	.00908	.01010	.02041	.03093	.05263	.11111	.25000	.66667	1
2	.12600	.13532	.14416	.15259	.22347	.28155	.38132	.59543	1.0000	2.0000	2
3	.39664	.41757	.43711	.45549	.60221	.71513	.89940	1.2708	1.9299	3.4798	3
4	.77729	.81029	.84085	.86942	1.0923	1.2589	1.5246	2.0454	2.9452	5.0210	4
5	1.2362	1.2810	1.3223	1.3608	1.6571	1.8752	2.2185	2.8811	4.0104	6.5955	5
6	1.7531	1.8093	1.8610	1.9090	2.2759	2.5431	2.9603	3.7584	5.1086	8.1907	6
7	2.3149	2.3820	2.4437	2.5009	2.9354	3.2497	3.7378	4.6662	6.2302	9.7998	7
8	2.9125	2.9902	3.0615	3.1276	3.6271	3.9865	4.5430	5.5971	7.3692	11.419	8
9	3.5395	3.6274	3.7080	3.7825	4.3447	4.7479	5.3702	6.5464	8.5217	13.045	9
10	4.1911	4.2889	4.3784	4.4612	5.0840	5.5294	6.2157	7.5106	9.6850	14.677	10
11	4.8637	4.9709	5.0691	5.1599	5.8415	6.3280	7.0764	8.4871	10.857	16.314	11
12	5.5543	5.6708	5.7774	5.8760	6.6147	7.1410	7.9501	9.4740	12.036	17.954	12
13	6.2607	6.3863	6.5011	6.6072	7.4015	7.9667	8.8349	10.470	13.222	19.598	13
14	6.9811	7.1154	7.2382	7.3517	8.2003	8.8035	9.7295	11.473	14.413	21.243	14
15	7.7139	7.8568	7.9874	8.1080	9.0096	9.6500	10.633	12.484	15.608	22.891	15
16	8.4579	8.6092	8.7474	8.8750	9.8284	10.505	11.544	13.500	16.807	24.541	16
17	9.2119	9.3714	9.6171	9.6516	10.656	11.368	12.461	14.522	18.010	26.192	17
18	9.9751	10.143	10.296	10.437	11.491	12.238	13.385	15.548	19.216	27.844	18
19	10.747	10.922	11.082	11.230	12.333	13.115	14.315	16.579	20.424	29.498	19
20	11.526	11.709	11.876	12.031	13.182	13.997	15.249	17.613	21.635	31.152	20
21	12.312	12.503	12.677	12.838	14.036	14.885	16.189	18.651	22.848	32.808	21
22	13.105	13.303	13.484	13.651	14.896	15.778	17.132	19.692	24.064	34.464	22
23	13.904	14.110	14.297	14.470	15.761	16.675	18.080	20.737	25.281	36.121	23
24	14.709	14.922	15.116	15.295	16.631	17.577	19.031	21.784	26.499	37.779	24
25	15.519	15.739	15.939	16.125	17.505	18.483	19.985	22.833	27.720	39.437	25
26	16.334	16.561	16.768	16.959	18.383	19.392	20.943	23.885	28.941	41.096	26
27	17.153	17.387	17.601	17.797	19.265	20.305	21.904	24.939	30.164	42.755	27
28	17.977	18.218	18.438	18.640	20.150	21.221	22.867	25.995	31.388	44.414	28
29	18.805	19.053	19.279	19.487	21.039	22.140	23.833	27.053	32.614	46.074	29
30	19.637	19.891	20.123	20.337	21.932	23.062	24.802	28.113	33.840	47.735	30
31	20.473	20.734	20.972	21.191	22.827	23.987	25.773	29.174	35.067	49.395	31
32	21.312	21.580	21.823	22.048	23.725	24.914	26.746	30.237	36.295	51.056	32

10.3 Subscribers Count Calculation In One Cell

We can calculate traffic by a subscriber (A_{sub}) [1]. Traffic is measured in Erlangs (E).

n – Count of connections during the 1-hour T – Average talk time during connection (sec) 3600 – 1 hour (3600 sec).

$$A_{sub} = \frac{n \times T}{3600}$$

Equation 5: | Subscriber Traffic Calculation

Research showed that Asub typically = 15-20 m [2]. We choose Asub = 20 mE = 0.02 E.

GoS = 2% = 0.02

For our cluster with 7/21 pattern, in case of for cell 4/32 (4carriers/32connections), cell's traffic connection channels = 32 – 2 (control channels) = 30, i.e., n=30

The traffic value for our cell in a cluster with a 7/21 pattern will find in the Erlang B as shown in (Table 3) below.

n	.007	.008	.009	.01	.02	.03	.05	.1	.2	.4	n
1	.00705	.00806	.00908	.01010	.02041	.03093	.05263	.11111	.25000	.66667	1
2	.12600	.13532	.14416	.15259	.22347	.28155	.38132	.59543	1.0000	2.0000	2
29	18.805	19.053	19.279	19.487	21.039	22.140	23.833	27.053	32.614	46.074	29
30	19.637	19.891	20.123	20.337	21.932	23.062	24.802	28.113	33.840	47.735	30
31	20.473	20.734	20.972	21.191	22.827	23.987	25.773	29.174	35.067	49.395	31
32	21.312	21.580	21.823	22.048	23.725	24.914	26.746	30.237	36.295	51.056	32

Figure 14: With 7/21 Pattern Cluster's Cell Traffic Value

So, A_{cell} = 21.932 E as justified in (Figure 14) above. The subscribers count per cell = $A_{cell} \div A_{sub}$ = 21.932 ÷ 0.02 = 1096 subscribers per cell.

10.4 Cell's Radius "R" Calculation. BTS Count

The final count of BS is determined by two parameters:

- Providing ongoing (continuous) radio coverage.
- Providing the required capacity.

to service the required number of subscribers aKeeping the requirements for signal strength and quality, we need to provide ongoing radio coverage of a given area. The count of BTS should be enoughnd support the required capacity.

Tripoli city:

- Has an area of about 1507 km2
- Number of people – 3 million.

The services' zone border already drew (page 5). It is around 1507 km2 area. About 1 500 000 – 1 700 000 potential mobile users can be available in Tripoli. In the near future, on startup, we can assume that we will have around 300 000 subscribers. We can provide service for 1096 subscribers per cell. So, we will need 300 000 ÷ 1096 = ~273-274 cells to provide service for 300 000 subscribers.

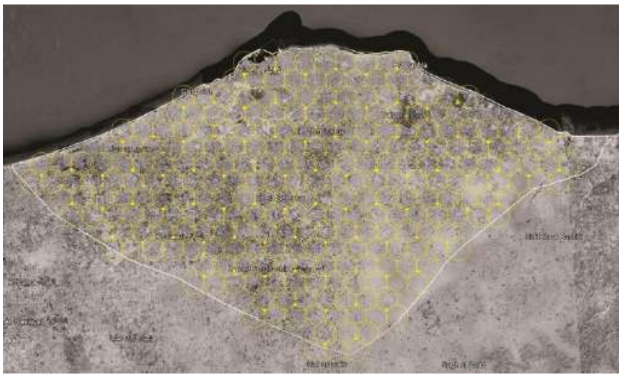
7/21 clusters have 21 cells and 7 BTS with 3 sectors, each BTS provides coverage for 3 cells, and each sector provides coverage for 1 cell. For 300 000 subscribers, we should have 273 ÷ 21 = 13 clusters. In total, for 300 000 subscribers, we should have 13 x 7 (or 273÷3) = 91 BTS. Assuming a uniform network load throughout the service area, also that our network should have 273 cells and taking into account that services an area of about 1507 km2, then each cell will have about 1507 ÷ 273 = ~ 5.6 km2 area. The cell's radius (R) can be calculated as the *following:*

$$S = \pi \times R^2$$
$$5.6 = 3.14 \times R^2$$
$$R^2 = 5.6 \div 3.14 = \sim 1.79$$
$$R = \sqrt{1.79}$$
$$R = \sim 1.34\ km$$

Equation 6: | Cell's Radius Calculation

10.5 Nominal Cell Plan

When drawing up the nominal plan we will assume that the load is evenly distributed throughout the service area. Our cell's R = 1.34 km, we should provide ongoing (continuous) radio coverage, so we will divide the selected area into 273 circles with R = 1.34 km (Figure 15).



Based on Figure 15 we will draw a nominal cell plan as shown in Table 4 and (Figure 16) below.

Table 4: Nominal Cell Plan Components

Cells	273
BSS (sites)	91
BTS	91
Clusters	13

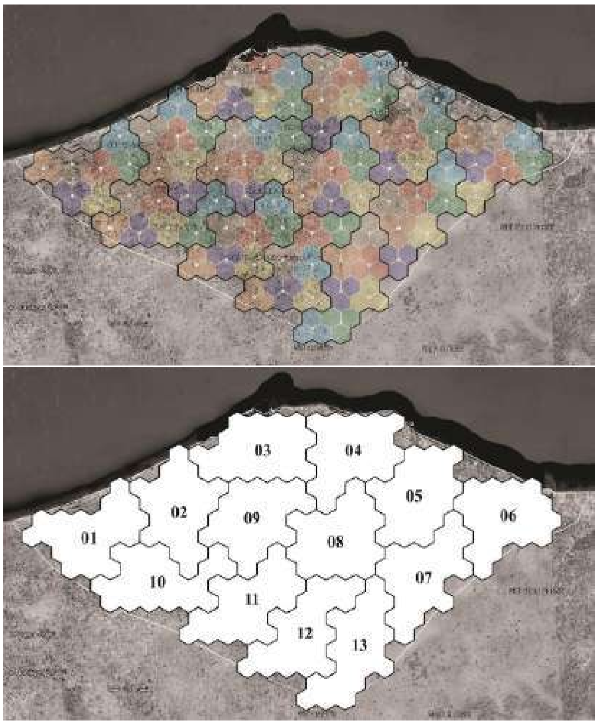


Figure 16: 7/21 Pattern Cluster's Cell Traffic Value

XI. RESULTS AND CONCLUSION

During our work, we based on provided in the research cellular networks base parameters, such as C/I, a spectrum, and full-duplex channel bandwidth values. Our network has an area of 1507 km2, in Tripoli city, Libya. There are about 1500000 – 1700000 potential subscribers can be available, but on startup, we designed our GSM-900 mobile network for around 300000 subscribers. Then, we planned and calculated additional investment for this network to provide service for additional 60000 subscribers. 60000 subscribers - this is a 20% increase in subscribers over the next 5 years. When designing a startup network for 300000 subscribers and drawing up the nominal plan, we assumed that the load is evenly distributed throughout the service area.

In a cellular network, when using directional radio propagation, the three cells group in one site and are covered by one BTS with three 1200-distributed sectors, one for each cell. Seven sites were grouped in one cluster that used the whole 20MHz range. So, our cluster was built with a 7/21 pattern, i.e., 7 sites/21 cells. The same frequencies can reuse many times in other clusters. We used FD and TD conceptions, where TD allows through one channel (carrier) has 8 connections. If we do not keep reserve frequencies for network future expansion, then in one cluster we have 100 carriers/800 connections per cluster, where for 16 cells the 5 carriers/40 connections per cell (5/40) and for the remaining 5 cells the 4carriers/32 connections per cell (4/32). In 4/32 cases each cell can provide service for up to 1096 subscribers. The network area was divided into 273 cells and each of them had about 1.34 km radius. So, to cover our network area we deployed 13 clusters with 91 BTS in total.

The network area's borders are not an ideal figure which can be covered with ideal form factor clusters, so when we deployed our cells and build clusters, as can see in the nominal plan, there are some territories which outside of our clusters' theoretical borders. Will we need to cover those zones too or not, it will be clear during the network working. During the network, working will be clear where will have more traffic loads and where will have fewer traffic loads too. Also, on startup, we don't know when will have an increase in subscribers by selected 20% (60 000 subscribers), where they increase the traffic loads, i.e., where we will need to deploy additional "powers", additional sectors, or BTS.

So, we must have reserved from available channels (carriers). Our cell count is calculated based on the data that each cell can support up to 1096 clients, i.e., in the 4/32 cells case. To have the reserved channels we may not use all available channels/carriers, i.e., some of them will reserve for the future. For example, we can from 5 carriers/40 connections (5/40) not use some carriers (channels) and reserve those. Or during the network work detect where have fewer loads and withdraw from those cells, the "extra" frequencies (channels).

In the work provided all the necessary information a provide information are discussed:

- About each channel bandwidth and spectrum length, about frequency range.
- About co-channel interference, how the type of cellular system is used (HEXAGONAL), and about co-channel tiers
- About cluster and cell size
- About clusters topology and cells position
- About why will use directional radio propagation (sectoring radio propagation)
- About Grade of Service (GOS)
- About subscribers count per one cell
- About cell radius, BTS counts, etc...
- Provide financing calculations, etc...

I.e., provide all technical details for the design and deployment network up to the "Nominal Plan" stage, because after that there should start work for territory surveys, radio propagation/ coverage simulation/calculation, final cell plan (final design) implementation, and so on. The listed, what should go after "nominal cell plan", does not include in this task, it is the other level in design (wrote about it in the introduction and in the results and conclusion). The "Nominal Cell Plan" is provided too.

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11.1 Starting Investment for Deployment of our Cellular Network

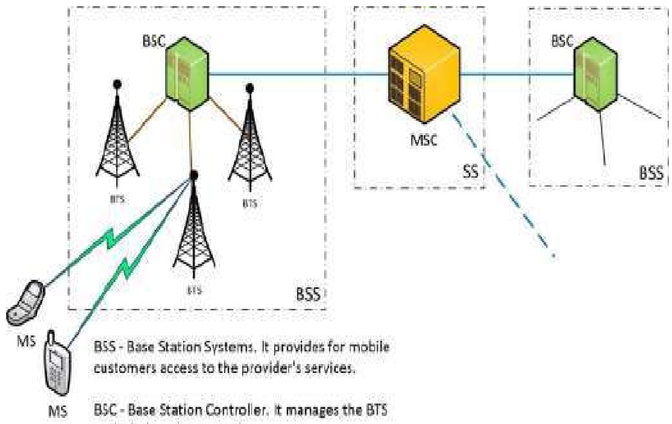

Figure 16: Cellular Network Work

In the research, as can be seen in Figure 16, we already provided a calculation for one BS (BSS = BSC+BTS). BSS = USD 100000K. It includes one BSC and one BTS with 3 sector TX (antenna + transmitter) (each sector cost = USD 50K) + all working which needs to mount stations on the necessary places. One BSC can support more than one BTS, but we will consider the situation when one BSC will support one BTS. For our start-up network, we need 91 BTS, i.e., 91 BSS. Investment for cellular stations should be = 91 x 100000K = 9 100 000 K. 10 100000K. In a market one BSS cost is about 50,000 EURO and provided an amount of 100000K USD is not real. There are included costs of all necessary OSS (Operation and Support System) and SS (Switching System) hardware that will be needed for this BSS operating. Also included is the necessary infrastructure cost, per one BSS, for example, FO networks or wireless networks [10].

Now will estimate the additional investment, in 5 years, in the case when we will have to increase subscribers by 20% (60 000 subscribers).

To provide service to an additional 20% of subscribers we can increase our network in a few *ways:*

- Every time, for every 20% additional subscriber, we will install additional BTS in those places where the network is overloaded. We will use the additional frequencies or bring it from reserved (3.2.2 Zone of transition). Also, we can reduce necessary cells' R, then will mount in the emerging "black holes" new BTS.
- Once increase capacity by 100% we will not do anything else, so far, the count of subscribers will be = 300 000 x 2 = 600 000.
- For additional users (20% - 60 000) we should mount the additional stations. We will not mount a new BSC, new BTS, and new sectoring can be managed by available BSC. We will mount new 60 000 1096 = about 55 new sectors/cells.

Additional investment, in this case, will be = 55 x 50K = 2 750 K.

In this case, we will not mount a new BSC also, we will reduce the size of our clusters by half and install additional 91 BTS, i.e., 91 x 3 = 273 new sectors.

Additional investment, in this case, will be = 273 x 50K = 13 650 K.

XII. CONCLUSION

The goal of this research was to build a cellular network that would cover 1507 square kilometers of land in Tripoli, Libya, with a population of over three million. There are 83 clusters composed of 12 cells each and over a hundred radio channels. Each cluster has three sectors and four directional antennas. We provided a complete solution for the design and implementation of Tripoli City's cellular network, including the various stages of the design process, such as the planning of the network, the radio propagation, and the simulation of the network.

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