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**Research Article**



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**Chemical and aroma volatile composition investigation  
on indigenous spices and vegetables to explore natural  
sensitizers**

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**Abstract**

The research was conducted to investigate the indigenous spices, vegetables and fruits of India to explore the natural sensitizers for dye sensitized solar cells. A series of spices and vegetables were extracted in different solvents. Best results were obtained in the chloroform and ethanol with some exceptions. These extracts were analyzed by UV spectrophotometer and thin layer chromatography. From absorption spectra and Rf values it can be suggested that natural pigments like Anthocyanins (465 nm), tannin (380 nm), carotenoids (380 nm), flavonoids (385 nm) and betalains (420 nm) may present in indigenous spices and vegetables. These pigments can be mostly used as sensitizers in the DSSC. In conclusion, results showed that many polyphenolic compounds are present in the carrot, tomato, eggplant, elaichi, loun and zeera.

**Keywords:** spices, vegetables, solar cells, UV spectrophotometer, DSSC.

**Introduction**

Use of fossil fuel in all human actions at large level led to a number of severe problems like environmental pollutions, acid rain, climatic changes, ozone depletion and global warming. It has been scientifically proven that these phenomenons are interrelated with the extensive use of fossil fuels. Fossil fuels give off the greenhouse gases like CO<sub>2</sub> and CH<sub>4</sub>. Today, about 20 × 10<sup>20</sup> Kg of CO<sub>2</sub> is put into atmosphere every year mainly by fossil fuels. Rapid economic growth and extensive use of fossil fuels by increasing population increased the acid rain. Acid rain has many influences on the natural ecosystem as well as environment such as acidification of soil, limited functioning of microorganisms and depletion of forest species. In China, acid rain pollution is tremendously increased due to rapid economic growth and energy demand and consumption. Acid deposition has occurred about 40% in the entire world especially in

the fast developing countries. Acid rain is mainly caused by the sulfur dioxide (SO<sub>2</sub>) and nitrogen dioxide (NO<sub>x</sub>) that on reaction with water in the atmosphere give rise to sulfuric acid nitric acid and mixture of many other acids. In the late 1990's, significant work has been done to reduce the precipitation of sulfate ion in the atmosphere but unfortunately, NO<sub>x</sub> emission have increased in alarming situation. Sulfuric acid rain (SAR) is now changed to mixed acid rain (MAR) and then to nitric acid rain (NAR). Change in the acid rain types may lead to serious environmental and ecosystem problems [1]. Fossil fuels like coal, oil, and gas cause the pollution in the form of carbon and sulfur. It is need of the hour to overcome the pollution by making efficient economic policies and replacing the fossil by new renewable energy resources like solar and wind power. Extensive use of the fossil fuels will reduce their availability in the

near future. Moreover, burning of fossil fuels causes the emission of CO<sub>2</sub> that ultimately affect the earth temperature as well as cause the air pollution. CO<sub>2</sub> may also provide payback for mankind. Many plants grow up healthier under increasing concentration of CO<sub>2</sub>.

Agriculture yield increases with increasing concentration of CO<sub>2</sub> and natural ecosystem can become extra green and resilient. Infertile environment and complex ecological exchanges bound the growth of the plant in increasing concentration of CO<sub>2</sub>. However, it is fact that there are more harms of CO<sub>2</sub> than benefits. Increasing concentration of CO<sub>2</sub> does not allow the harmful radiation to go back into the space; as a result the earth temperature is increasing day by day. Increase in temperature is causing serious problems in human daily activities. In order to keep away from more impacts of these phenomena's, two alternative proposals are made; one is to develop the quality of fossil fuel and other is to replace fossil fuel usage with renewable and environmental friendly energy sources. Solar energy is most suitable source of renewable energy when we compare it with geothermal, wind, hydro and tidal energies [2].

Climate change and global warming are main threats to human societies and fundamentally associated with energy consumption and green-house gases (GHG) emissions. The urban areas which have high population rate are considered to responsible for 27% energy consumption and 17% carbon dioxide emissions, respectively, has a considerable role to mitigate global climate change. Some of developed countries like Germany, China, Canada, US, Japan and Russia and developing countries like India, South Korea and Iran account for two-thirds of global CO<sub>2</sub> emissions. Residential energy consumption and GHG emissions of these countries have direct and significant effects on the environment of the world. It was found that global residential energy consumption grew by 14% from 2000 to 2011. Most of this increase has occurred in developing countries, where population, urbanization and economic growth have been the main driving factors. Among the ten studied countries, all of the developed ones have shown a promising trend of reduction in CO<sub>2</sub> emissions, apart from the US and Japan, which showed a 4% rise. Globally, the residential energy market is dominated by traditional biomass (40% of the total) followed by electricity (21%) and natural gas (20%), but the total proportion of fossil fuels has decreased over the past decade. Energy policy plays a significant role in controlling energy consumption. Different energy policies, such as building energy codes, incentives, energy labels have been employed by countries. Those policies can be successful if they are enhanced by making them mandatory, targeting net-zero energy building, and increasing public awareness about new technologies. However, developing countries, such as China, India and Iran, still encounter with considerable growth in GHG emissions and energy

consumption, which are mostly related to the absence of strong and efficient policy [3]. It is observed that there is a relationship between CO<sub>2</sub> emission and natural resources depletion in some Asian countries like India, Nepal, India, Sri Lanka and Bangladesh. The research data exhibits that there is direct relation between CO<sub>2</sub> emissions and natural resources depletion. It was concluded that GDP (Gross domestic product) and poor living standards has a positive effect and CO<sub>2</sub> emissions has a harmful effect on energy fabrication. In the same way, higher energy fabrication leads to reduce emission of carbon [4].

### **World energy consumption**

It has been estimated that world is consuming energy at a rate of 4.1×10<sup>20</sup> joules/Anum. This consumption is equal to or 13 terawatts (TW) or 13 trillion watts. It is expected that in 2050 World energy consumption will be reached up to 25-30 TW and 40-50 TW in the beginning of next century.

U.S Energy information administration reported that during the years of 2010-2040, there will be a great demand of energy which will be 56% more than current consumption. Increase in this demand of the energy will come from non-OECD (non-Organization for Economic Cooperation and Development) countries. In these countries demand is high due to strong economic growth. Non-conventional energy sources like solar, wind and nuclear power are fastly growing in the world. However, fossil fuels can supply up to 80% of the energy of the world till 2040 [5]. Large amount of the energy is being consumed in the industrial sector and is estimated that in 2040 this demand of industrial sector will be more than half of global energy. It is expected that excessive use of the fossil fuel will increased the carbon dioxide emissions upto 45 billion metric tons in 2040 which is 46% more than 2010. It is observed that those countries that continuously depending on the fossil fuels for energy requirement increased the CO<sub>2</sub> emission.

### **Energy crisis in India**

The energy crisis has paralyzed the economy of India. The Circular debt reached to Rs. 251 billion in June 2014; however there is a bundle of issues behind the energy crisis. Most of the generation of electricity is oil depended, while oil and gas companies stop the supply to production companies due to financial matters that make the load shedding situation more critical. Oil prices are going high which directly raise the unit price of electricity. Above all, inadequate tariff price levels affect the production industry and the economy. Furthermore, IPPs (Independent power producers) are working under take-or-pay agreement so the Government is obliged to pay a prescribed amount based on the agreed minimum level of power sale, even if oil supply is halted and the Government takes less power than the agreed minimum.

Table 1.1 shows the energy consumption in different sectors of India. Domestic and agriculture user cumulatively utilizes 60% of the overall energy. Demand from these two sectors is seasonally dependent and increased in summer season. Demand of electricity was 11,081 MW in November 2010 which

dramatically increases up to 18,511 MW in June 2011 with the difference of 7400 MW. In year 2013, only the chief minister of Punjab distributed 15 W solar panels among the students, which definitely cannot support the severe energy crises [6].

Table 1.1 shows the energy consumption

Sector	Punjab (GWh)	Sindh (GWh)	KPK (GWh)	AJK (GWh)	Baluchistan (GWh)	Total (GWh)
Agriculture	6.8	1.2	0.5	0.0	4.1	13.0
Bulk supply	3.5	1.7	0.7	0.0	0.1	5.9
Domestic	28.0	9.3	7.3	0.8	0.6	46.1
Industry	18.3	6.1	1.9	0.1	0.2	26.7
Commercial	4.7	2.00	0.7	0.1	0.1	7.5
Other	0.3	0.3	0.0	0.1	0.0	0.7
Total	61.7	20.6	11.1	1.1	5.5	74,349

In India, energy is one of the major problems due to higher demand and low production. India is facing serious energy crisis and most of the northern areas have not yet supplied the electricity. It is the need of the hour to work on the alternative and renewable resources of electrical energy. Energy supply and demand gap is very large. Due to energy shortfall there is 10-12 hours shortfall in the big cities and 16-18 hours in the country sides. Some indigenous source like hydro-power and thermal power are in progress and not sufficient to overcome the energy shortfall. India has limited fossil fuel resources and needs to import fossil fuel, but the poor economy does not allow importing fossil fuel at a large scale. India is situated in the utmost solar isolation area in the Earth. To overcome the energy shortfall in India it is necessary to expand native energy resources like hydropower, solar and wind. The potential of renewable energy resources can be used to electrify the off-grid areas in the western deserts and northern regions. Instead of electricity produced on large scale, solar energy also has some applications such as solar cookers and solar water heaters. Utilization of this economical renewable energy source requires some significant efforts. European Union (EU) has made the new rule that being a member of EU each country should produce at least 22.1% of their energy from alternative energy sources. India can also fulfill its need by following this rule and can be an environmentally friendly nation. By developing the solar power plants in India, our economy will not be affected by the increase in oil prices [7].

In India, most of the areas receive high solar radiation intensities in a long season of summer. The potential of solar and renewable energy was extensively studied by the researcher in India. But unfortunately due to lack of good policies major part of up to 38% is produced by expensive oil and renewable energies are not taken into account seriously. In the early 90's, solar cells with the capacity of 440 W were installed for village electrification in different areas but they became un-operational very soon due to lack of interest and follow up. In May 2001 India council of renewable energy technologies (PCRE) was established. For making the PCRE the National Institute of Silicon Technology (NIST) and India Council of Appropriate Technology (PCAT) were in alliance together. But progress of this council is very slow and still any mega project of solar energy is not initiated. Generation of electricity through solar cell is extremely small in amount [3]. But with the high index of light we can increase the PV capacity which is 100 kW at this time. Solar energy is an excellent alternative source to lessen the load shedding in the rural and urban areas of the India [8].

In 2012, India has moved head in the field of solar power by establishing first solar cell plant in Islamabad with project title of "introduction of clean energy by solar electricity generation system". In a long term policy, India has also set an aim to add 5% electricity in the system from solar power by year 2030.

Government of Punjab is taking initiative on solar energy to resolve the load shedding issue up to maximum level. Energy department of the Punjab has begun the project of 1000MW of solar power with the name of Quid-e-Azam solar park in the

desert of the Bahawalpur. This project will start working by the end of 2015 and will be helpful in the recent shortfall as well as the energy needs of the people of the dessert of Punjab. A project of 2000 MW was signed by the Asian development bank and government of Punjab. That project is based on public-private partnership and will be completed in the year 2015. Chinese and Turkish companies are also taking interest to invest in energy sector of India. China power investment corp (CPI Group) has shown keen interest in four power projects. Projects of 660 MW and 300 MW will be installed in Lahore and Bahawalpur respectively [9].

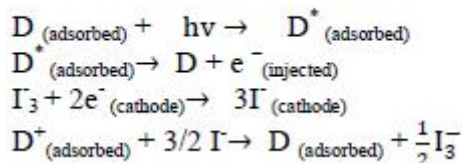
### Solar Energy

The sun is the clean and renewable source of energy that deposits 120,000 TW of radiation on surface of earth. To utilize this form of energy several techniques are in pipeline but still high cost of photovoltaic panel and the stability of current PV devices have limited the use of solar power at large scale. It is the need of the hour to develop new, more advanced, efficient and cheaper solar energy techniques so that solar power should available to large numbers of customer at low cost. The sun emits radiation in ultraviolet to visible region giving peak in visible region. At the temperature of 5250K, this spectral absorption is similar to the absorption of the spectrum of blackbody. However, the position of the sun and atmospheric absorption interfere the spectral absorption of the sun radiation. When the sky is clear and sun is directly overhead then, maximum radiations of shortest wavelength through the atmosphere come on the earth. The wavelength is known as the air mass (AM) and can be represented as,  $AM = 1/\cos \theta$ , here  $\theta$  is the angle of altitude of sun. When  $\theta$  is 420 then the standard solar spectrum used of solar cells is AM = 1.5G (global). This spectrum is normalized to get the integrated irradiance that is 1000 Wm<sup>-2</sup>[10].

### Component of the DSSC

Visible light is converted into the electricity by the DSSC on sensitization of the semiconductors. DSSC consist of the following components. Photoelectrode having photosensitizer, Semiconductor film electrode, Counter electrode, Redox electrolyte

### Mechanism of DSSC



Thickness and the surface area of the semiconductor film determined the Efficiency of dye-sensitized solar cells. Large surface area will increase dye loading. So, more chance to harvest the light [11].

### Types of sensitizer

Photosensitizers have the ability to absorb and convert the sun light and in to the electricity called photosensitizers. Researcher divided the photosensitizers in to two categories.

- Commercial dye sensitizers.
- Natural sensitizers.

### Materials and Methods

#### Chemicals used

Absolute Ethanol (99.9%), Dichloromethane (99.9%), Distilled Chloroform (99.9%), Distilled water  
It was make sure that pure solvents were used for extraction. Solvents were purified by distillation and preserved in the dry bottles.

#### Apparatus and instruments

Digital UV spectrophotometer (Agilent Technologies, Carry 60 UV-VIS), Funded by IFS (International foundation for Science Sweden), TLC cards, UV lamp 254-366 nm (CANAG), Digital weighing balance (SHWAN), Beakers, Pipette, Piston and morta

#### Future prospects


From current study some potential targets are selected for further investigation. In future, on these candidates it is planned to carry out following research work.

- Separation and purification of crude extracts by HPLC and conventional column chromatography.
- Structural characterization of purified dyes by 1H-NMR, FTIR spectroscopy and mass spectrometry.

- Study of photoelectrochemical and photophysical properties of dyes.
- Fabrication of DSSC by using these dyes and studies their overall efficiency.

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