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Dear Esteemed Readers, Authors, and Colleagues,

I hope this letter finds you in good health and high spirits. It is my distinct pleasure to address you as the Editor-in-Chief of Integrative Omics and Applied Biotechnology (IIOAB) Journal, a multidisciplinary scientific journal that has always placed a profound emphasis on nurturing the involvement of young scientists and championing the significance of an interdisciplinary approach.

At Integrative Omics and Applied Biotechnology (IIOAB) Journal, we firmly believe in the transformative power of science and innovation, and we recognize that it is the vigor and enthusiasm of young minds that often drive the most groundbreaking discoveries. We actively encourage students, early-career researchers, and scientists to submit their work and engage in meaningful discourse within the pages of our journal. We take pride in providing a platform for these emerging researchers to share their novel ideas and findings with the broader scientific community.

In today's rapidly evolving scientific landscape, it is increasingly evident that the challenges we face require a collaborative and interdisciplinary approach. The most complex problems demand a diverse set of perspectives and expertise. Integrative Omics and Applied Biotechnology (IIOAB) Journal has consistently promoted and celebrated this multidisciplinary ethos. We believe that by crossing traditional disciplinary boundaries, we can unlock new avenues for discovery, innovation, and progress. This philosophy has been at the heart of our journal's mission, and we remain dedicated to publishing research that exemplifies the power of interdisciplinary collaboration.

Our journal continues to serve as a hub for knowledge exchange, providing a platform for researchers from various fields to come together and share their insights, experiences, and research outcomes. The collaborative spirit within our community is truly inspiring, and I am immensely proud of the role that IIOAB journal plays in fostering such partnerships.

As we move forward, I encourage each and every one of you to continue supporting our mission. Whether you are a seasoned researcher, a young scientist embarking on your career, or a reader with a thirst for knowledge, your involvement in our journal is invaluable. By working together and embracing interdisciplinary perspectives, we can address the most pressing challenges facing humanity, from climate change and public health to technological advancements and social issues.

I would like to extend my gratitude to our authors, reviewers, editorial board members, and readers for their unwavering support. Your dedication is what makes IIOAB Journal the thriving scientific community it is today. Together, we will continue to explore the frontiers of knowledge and pioneer new approaches to solving the world's most complex problems.

Thank you for being a part of our journey, and for your commitment to advancing science through the pages of IIOAB Journal.



Yours sincerely,

Vasco Azevedo

Vasco Azevedo, Editor-in-Chief
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ARTICLE

SEALING ABILITY OF CPOINT -SMART PASTE BIO VERSUS
GUTTA PERCHA- AH PLUS USING GLUCOSE LEAKAGE
MODEL: AN IN-VITRO STUDYSarika Chandra, Sylvia Mathew*, B.V.Sreenivasa Murthy, Poornima Ramesh, John V. George,
Swaroop HegdeDept. of Conservative Dentistry and Endodontics, Faculty of Dental Sciences, Ramaiah University of
Applied Sciences, Bengaluru, INDIA

ABSTRACT



Background: To compare the sealing efficacy of CPoint- SmartPaste Bio system and Gutta percha -AH plus using a Glucose Leakage Model. **Method:** 50 extracted human mandibular premolar teeth were decoronated and chemo-mechanical preparation performed for all the samples. They were divided into Group I and II (n=20) and control groups Group III and IV (n=5). Samples in Group I were obturated using CPoint and SmartPaste Bio and Group II with Gutta percha and AH plus sealer. Group III, positive control were obturated with Gutta percha without any sealer. Group IV, negative control samples were coated with nail varnish completely. The prepared samples were subjected to microleakage testing using the Glucose Leakage Model. Aliquots of 10 µL were drawn using micropipettes on day 1 and Week 1,2,3,4,5,6,7, 8 and subjected to Glucose oxidase -Peroxidase testing. The optical density reading was obtained using a dual-wave spectrophotometer at 505 nm. Data was analysed using SPSS (Statistical Package for Social Science, Ver.10.0.5). **Results:** Leakage was observed in all groups except for Group IV. Leakage in Group II and Group I, significantly increased from the 4th week. The mean values at the end of 8 weeks was greater for the samples of Group I, CPoint- SmartPaste Bio as compared to Group II, Gutta percha - AH plus though not statistically significant. **Conclusions:** The microleakage observed with CPoint- SmartPaste Bio (Group I) was similar to that of Gutta percha-AH plus (Group II) thus suggesting similar sealing ability of both obturating materials.

INTRODUCTION

Root canal filling materials must seal the canal three dimensionally to prevent ingress of microorganisms or toxins into the canal space; that is to achieve a "fluid tight seal"[1,2]. Innumerable materials have been formulated to enable effective and complete sealing of the root canal system. Wu and Wesselink have concluded that due to the discrepancy in results, it is difficult to draw conclusions as to which filling material or technique is the best to seal the root canal system [3].

In the past decade, a wide variety of rotary Ni-Ti instruments have been developed and marketed to facilitate the tedious and challenging process of cleaning and shaping of the root canals. Single gutta percha cones matching the geometry of these Ni-Ti files have also been fabricated for ease of obturation of the prepared canals. Single cone obturation points and sealers result in a uniform mass thus eliminating the need of accessory cones [4].

Obturating materials do not have fixed, inert and impenetrable borders but have dynamic micro crevices, which contain busy traffic of bacteria, ions, and molecules [5]. Microleakage (apical or coronal) is a major factor determining the clinical and biological outcome of root canal treatment. Therefore in-vitro assessment of microleakage of any novel obturating material is important before incorporating it into clinical practice.

Endo Technologies, LLC, USA has launched a novel point and paste root canal filling technique called the C Point system. C stands for the Latin word "cresco" (crescendo), which means to grow, expand or increase. As the name suggests, CPoints are designed to expand laterally without expanding axially by absorbing residual water from the instrumented canal space [6]. It is used with an accompanying resin based bioceramic sealer, marketed as SmartPaste Bio.

The different techniques devised for the evaluation of microleakage include: assessment of linear and volumetric dye penetration, autoradiographic detection of isotope penetration, radionuclide detection, culture techniques to detect bacterial penetration, salivary penetration models, fluid filtration techniques, fluorometry, intra-canal reservoir techniques, electrochemical techniques etc. In 2007, the Editorial Board of the Journal of Endodontics declared that 'sealability studies comparing endodontic procedures using the penetration of dyes, chemicals etc. are not useful to endodontic science and the Editorial Board has agreed to restrict publication of sealability studies using these techniques'. Trying to overcome the drawbacks of the other microleakage techniques Xu et al. developed the Glucose Leakage Model in 2005 which uses glucose as a tracer molecule [7,8].

The knowledge of the sealing efficacy of any obturation material is incredibly essential as it is one of the principal factors governing the clinical outcome of endodontic treatment. Therefore, the aim of this study was to assess and evaluate the sealing efficacy of CPoint-SmartPaste Bio against the most prevalently used method, gutta percha in combination with AH plus sealer.

KEY WORDS

CPoint - SmartPaste Bio;
Glucose Leakage Model;
Gutta percha -AH plus

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*Corresponding Author
Email:
sylviamathew@gmail.com
Tel: +91-080-23602079

MATERIALS AND METHODS

Fifty human mandibular premolar teeth extracted for orthodontic purpose was selected for the study. All teeth were decoronated using a safe- sided diamond disc and root lengths were standardized to 15mm. Access was gained using a #2 endodontic access diamond bur (Dentsply Maillefer, Ballaigues, USA) and patency was established using a #10 K file (Mani Inc., Japan). Chemo-mechanical preparation was done till #30/0.06 using the RaCe rotary Ni-Ti system (FKG Dentaire, Suisse, Switzerland) with copious irrigation using 3% Sodium hypochlorite. After completion of the chemo-mechanical preparation, irrigation was done with an additional 3 ml of 3% sodium hypochlorite. This was followed by irrigation with distilled water and then 1ml of 17% EDTA to remove the smear layer. Final irrigation was done with distilled water. The teeth were then randomly divided into 2 experimental groups (n=20 each) and 2 control groups (n=5 each).

The samples in the 1st experimental group; Group I (n= 20) were obturated using CPoint and SmartPaste- Bio sealer (EndoTechnologies, LLC, Shrewsbury, MA,USA) as per the manufacturers' instructions. The samples in Group II (n= 20) were obturated using gutta percha points with AH plus sealer (Dentsply Maillefer, Ballaigues, USA) using lateral condensation technique. The positive control group (Group III) consisted of teeth obturated with gutta percha without the use of any sealer. The teeth in the negative control group (Group IV) did not receive any treatment and were sealed externally with two coats of nail varnish.

The teeth were subsequently mounted in the Glucose leakage model, as proposed by Xu et al for evaluation of microleakage [7]. 10 μ L of sample from the lower chamber of the glucose leakage model was withdrawn with the help of a micropipette on day 1 and weeks 1,2,3,4,5,6,7 and 8. The lower chamber was replenished with 10 μ L of 0.2% sodium azide each time a sample was withdrawn for evaluation. The sample withdrawn was subjected to Glucose- oxidase and peroxidase (GOD-POD) testing. The optical density of the solution obtained after subjecting the sample to GOD-POD testing was evaluated using a spectrophotometer (Elico double beam UV visible spectrophotometer SL 164, India) set at 505 nm.

RESULTS

Leakage was observed in both the experimental groups, which was time dependant. There was a substantial increase in leakage from the fourth week onwards in both the experimental groups with CPoint – SmartPaste Bio exhibiting more leakage than teeth obturated with gutta percha – AH plus [Fig. 1].

TABLE 1: Inter- group comparison in the micro leakage values obtained using a Spectrophotometer

Visit	Pair wise comparison (p value)		
	Group I vs II	Group I vs III	Group II vs III
Day 1	0.984	<0.001	<0.001
Week 1	0.974	<0.001	<0.001
Week 2	1.000	<0.001	<0.001
Week 3	0.999	<0.001	<0.001
Week 4	0.793	<0.001	<0.001
Week 5	0.291	<0.001	<0.001
Week 6	0.321	<0.001	<0.001
Week 7	0.304	<0.001	<0.001

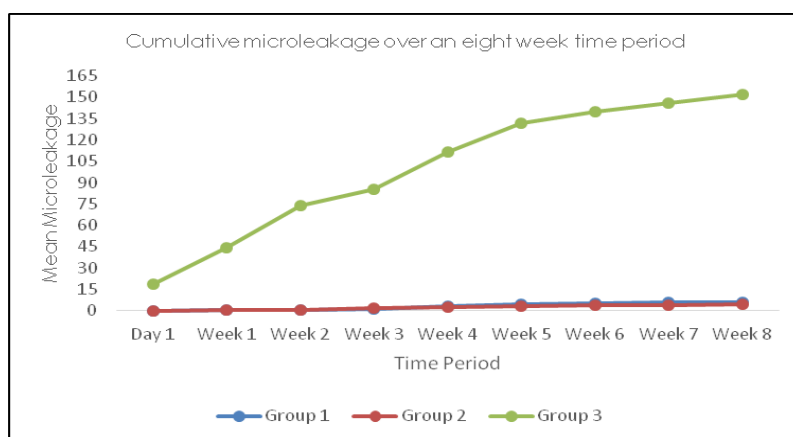


Fig. 1: Cumulative micro leakage of Groups I, II and III over an eight week time period.

DISCUSSION

The ultimate goal of root canal treatment is to prevent reinfection of the root canal through an impermeable fluid tight seal achieved by means of a three dimensional obturation of the root canal system. C-Point is a novel obturating material that is said to exhibit non- isotropic lateral expansion to enhance the sealing ability of the material. This study was hence undertaken to evaluate the sealing ability of CPoint; in conjunction with Smart Paste Bio using the Glucose Leakage Model.

At the end of the test period it was observed that Groups I, II and III exhibited significant leakage, establishing a positive correlation between leakage and time. The mean leakage values in Groups I and II were found to be similar from day 1 to week 3. At the 4th week, the leakage values for both these groups were found to be significantly more as compared to their baseline values. At the end of the test period, the mean leakage value for Group I was 6.624 ± 1.771 and for Group II 4.449 ± 1.777 , showing significant glucose leakage in both groups [Table 1]. The mean leakage value was found to be greater for Group I as compared to Group II at the end of 8 weeks, but this difference was not statistically significant. The performance of CPoint- SmartPaste Bio seemed to deteriorate with increasing time.

The lateral expansion of CPoint is claimed to occur non-uniformly, with the expandability depending on the extent to which the hydrophilic polymer is pre-stressed (i.e. contact with a canal wall will reduce the rate or extent of polymer expansion) [9]. As claimed by the manufacturer, gaps may still remain between the walls of the canal and the expanded point. Consequently, an accompanying sealer must be used to seal those areas. Therefore the accompanying sealer used is a resin-based sealant with the addition of bioceramic marketed as SmartPaste Bio. SmartPaste bio produces calcium hydroxide and hydroxyapatite as by- products of the setting reaction, rendering the material both anti-bacterial while setting and biocompatible once set. It has a delayed setting time of 4-10 hours enabling expansion of the CPoint thereby facilitating filling of any voids, as put forth by the manufacturers. The results of our study contradict the claims about the superior sealing ability of CPoint [6].

The proposed explanation for the greater leakage of CPoint/SmartPaste Bio in our study is based on the interaction of water with hydrophilic copolymers such as CPoint. CPoint is composed of an inner core of Nylon with a polymeric coating. The inner core of CPoint is a mix of two proprietary nylon polymers: Trogamid T and Trogamid CX. The polymer coating is a cross-linked copolymer of acrylonitrile and vinylpyrrolidone, which has been polymerised and cross-linked using allyl methacrylate and a thermal initiator. CPoint expands when in contact with water due to the affinity of the polymeric coating for water. Vinylpyrrolidone [10] and Acrylonitrile [11] have polar functional groups. Hydrophilic polymers owing to their polar functional groups are able to absorb and adsorb large volumes of water, which can affect their functionalities [12]. The interaction of water lowers the glass transition temperature due to its universal plasticizing activity. During the study it was noticed that prior to contact with water, CPoint was rigid in nature. However, after contact with water it turned into a more rubbery consistency. This is consistent with the aforementioned statement about the effect in glass transition temperature on contact with water.

The underlying molecular mechanism proposed is the binding of water molecules to the polar groups of the materials, that weaken the attraction forces between the polymer chains, consequently increasing the free volume. Water molecules may penetrate into the hydrophilic polymer matrix, increasing the distance between the polymer chains thus providing more free volume for molecular movements [13]. At higher moisture levels water molecules weaken the hydrogen bonds between polymer chains and lead to the plasticization of the material and increased free volume [14]. This can lead to the presence of microscopic voids [15] within the polymeric matrix, which in turn could provide a pathway for leakage of the glucose tracer molecule. Similar to other copolymers, water absorption by vinylpyrrolidone-acrylonitrile copolymer affects the biocompatibility of the material [16], as leaching of water-solubilised materials may occur [17]. However, Eid et al evaluated the biocompatibility of CPoint and concluded that the in vitro biocompatibility is comparable to gutta-percha with minimal adverse effects on osteogenesis after elution of potentially toxic components [18].

In the present study, glucose was selected as the tracer molecule because it has a small molecular size (MW = 180 Da) and is also a nutrient for bacteria. If glucose can enter the canal from the oral cavity, bacteria that may survive root canal treatment could multiply and potentially lead to periapical inflammation. To determine the concentration of glucose, the enzymatic glucose oxidase- peroxidase method (GOD-POD method) was chosen because it provides a higher degree of specificity and sensitivity when compared to other methods, such as copper or ferricyanide methods [19]. In this method, glucose is oxidized by the enzyme glucose oxidase in the presence of oxygen to gluconic acid with formation of hydrogen peroxide. Then in the presence of a peroxidase enzyme, a chromogenic oxygen acceptor (4-aminoantipyrine and phenol) is oxidized by the hydrogen peroxide, resulting in the formation of a red product, which is an oxidized chromogen [7]. The quantity of this oxidized chromogen is proportional to the glucose present initially in the first reaction, the quantity of which is determined using a dual- wave spectrophotometer. This model enables us to quantify the endodontic microleakage cumulatively over time. In addition, the coronal low pressure could help rule out entrapped air or fluid and seemed to be sufficient for a device with high sensitivity [20].

As the Glucose Leakage Model is manually assembled, there could be some variations in readings within every group, accorded to human error. Additionally, the obturating materials may potentially react with glucose

as demonstrated in a study by Shemesh et al.[8] Further research on the structure, biocompatibility and sealing ability of CPoint needs to be undertaken.

CONCLUSION

Within the limitations of this study, it was observed that both the experimental groups exhibited leakage as recorded using Glucose leakage model and this leakage was time dependant.

CONFLICT OF INTEREST

Authors deny any conflict of interest related to the study

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ARTICLE

PERFORMANCE EVALUATION AND COMPARATIVE ANALYSIS OF
A LOW COST NON CYCLIC INTEGRATED REFRIGERATION AND
HEATING SYSTEM IN BOTSWANA

Abhishek Agarwal*, Obusitswe Makgotla Seretse, Thabang Kablay, Isaac Pitso

Department of Mechanical Engineering, University of Botswana, Gaborone, BOTSWANA

ABSTRACT



Due to the energy costs associated with refrigeration and environmental problems associated with refrigerants, an alternative refrigeration system is required to replace the current refrigeration systems and refrigerants. In this study, a liquefied petroleum gas refrigeration system is designed and fabricated in order to solve the problems stated above. Liquefied petroleum gas is an environmentally friendly refrigerant as it has zero ozone depletion potential and has a low global warming potential of 1. The refrigeration system designed in this study does not use electric power for operation but rather, it uses liquefied petroleum gas which is contained in a cylinder at a pressure of 12.5 bar. Liquefied petroleum gas is passed through the evaporator where it gives the refrigeration effect, afterwards, it is passed to the stove where it is combusted to give heat energy. Therefore, the liquefied petroleum gas refrigeration system gives the dual purpose of refrigerating and heating simultaneously. The refrigeration system designed, has coefficient of performance of 3.24 which is higher than that of domestic refrigerators which use R134a as a refrigerant. This COP is achieved using a mass flow rate of 9.52×10^{-4} kg/s. The refrigeration capacity of this refrigeration system is 240W and the minimum temperature at which this refrigeration system operates is -13°C .

INTRODUCTION

Refrigeration is the process of extracting heat from a substance and maintaining the temperature of the substance below that of the surroundings. The process of extraction heat must be carried out continuously as heat from the surrounding will be transferred to the space being refrigerated. A refrigerator is one of the appliances which are running throughout the whole year without being stopped, which have resulted in making refrigerators one of the most energy consuming domestic appliance. Therefore it would be important to develop a low-cost refrigeration system which does not consume electric energy. As a result of the Montreal protocol signed by the United Nations (UN) in 1987 the chlorofluorocarbons (CFCs) refrigerants were banned for use as they are known to be damaging the ozone layer. Due to environmental problems associated with refrigerants, a lot of currently used refrigerants have come under criticism. The commonly used refrigerant, R-134a, although having zero ozone depletion potential, has a high global warming potential of 1300 [1]. As a consequence of these environmental problems, researches are being carried out around the world to come up with an environmentally friendly refrigerant. This study investigates the use of LPG in refrigeration systems as a refrigerant. LPG is an environmentally friendly refrigerant as it does not have ozone depletion potential [2]. The use of LPG as a refrigerant will be convenient for refrigeration in regions where there is no supply of electric energy, as this study proposes LPG refrigeration system which does not use electric power. The refrigeration system presented in this study serves the dual purpose of refrigeration and producing heat in a stove.

PROBLEM STATEMENT

The consumption of energy, which is usually in the form of electrical energy, used by refrigeration systems is high. This makes the operating cost of refrigeration systems particularly high because refrigeration systems are appliances which are run throughout the whole year in industries as well as in homes [3]. This puts pressure on suppliers of electric energy to produce more electricity for supply. However, there has been shortage of electric power in Botswana and many countries around the world.

There is need for alternative refrigeration in the rural areas of Botswana where there is no or limited supply of electric energy [4]. Refrigeration systems are an essential appliance in homes and industries as they are used for preservation of food and other industrial processes. This is especially true in cattle post where there is need for refrigeration of meat and dairy products. It is therefore important to ensure that all homes and industries, including those in rural areas where there is no electricity, should have refrigeration systems. Halo carbon (HC) refrigerants have been the most used refrigerants up until now, due to their good thermodynamic properties required for refrigeration [5]. He went on to state that, the problem associated with these refrigerants is that they have high ozone depletion potential. The refrigeration industry is now in turmoil and will remain so for some years ahead as chemists try to find replacement refrigerants for those causing damage to the ozone layer.

As a consequence of the problems outlined above, there is a need for a new refrigerant required to replace the currently used harmful refrigerants. Baskaran and Mathews (2012) [6] stated that R134a has been used to replace these halo-carbon refrigerants because it has zero ozone depletion potential, but it has been observed that R134a has a high global warming potential of 1300. Therefore, there is a need for an environmentally friendly refrigerant which does not have ozone depletion potential and has no or low global warming potential too.

KEY WORDS
Alternative refrigerant,
propane, CFCs,
coefficient of
performance,
evaporator

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****Corresponding Author**
Email:
agarwala@ub.ac.bw
Tel.: +267-355-4307

REFRIGERATION SYSTEMS

To achieve refrigeration in home and industries several refrigeration systems have been developed, the cyclic refrigeration system and the non-cyclic refrigeration system being the most common. These refrigeration systems are described below.

Cyclic Refrigeration

The cyclic refrigeration process is the most used refrigeration process in both homes and industries. The cyclic process allows heat to be extracted from the evaporator at low temperature and low pressure. This heat is then transferred to the surroundings at higher temperature and higher pressure, in the condenser. The block diagram in [Fig. 1] shows the cyclic refrigeration processes explained by Nag [5].

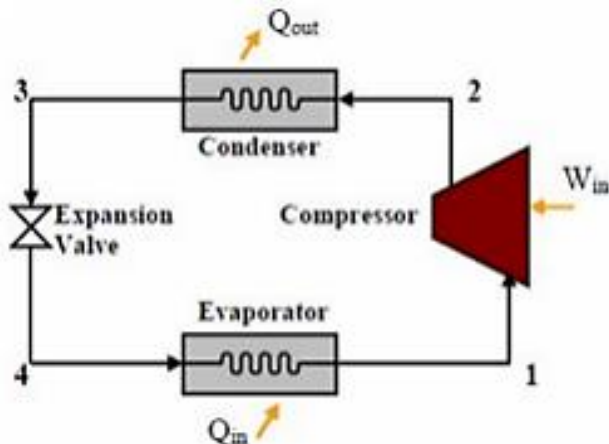


Fig. 1: Vapour compression refrigeration system cycle. [5]

Refrigeration compressors often utilize electric motors. The compressor has to be running continuously as the refrigeration system operates on a continuous basis. As refrigeration systems are appliances which are kept running for the whole year non-stop, they end up consuming a lot of electric energy, making refrigeration an expensive process.

Non-cyclic refrigeration system

The non-cyclic refrigeration system is one of the earliest refrigeration systems used. In this refrigeration, a cold substance known as a refrigerant is used to absorb heat from an evaporator, and the refrigerant is discarded after absorbing heat. Melting of ice or snow was one of the earliest non-cyclic refrigeration methods and is still employed. Ice melts at 0°C . When it is placed in an evaporator, it absorbs the heat and then melts. After melting, it is discarded and replaced with new ice. This type of refrigeration system is of low cost when there is free abundant ice, like in the arctic region of the earth where there is abundant ice. Nag (2009) [5] further went on to state that another medium of non-cyclic refrigeration is solid carbon dioxide. "At atmospheric pressure, carbon dioxide cannot exist in a liquid state, and consequently, when solid carbon dioxide is exposed to the atmosphere, it sublimates, i.e. it goes directly from solid to vapour, by absorbing the latent heat of sublimation (620 kJ/kg at 1 atm , -78.5°C) from the surroundings. The carbon dioxide is then discarded after absorbing heat. The low temperature of -78.5°C at which carbon dioxide sublimates makes it suitable for low temperature refrigeration.

The LPG refrigeration system presented in this study uses the Non-cyclic Refrigeration system type. This is effective because LPG is abundant and is sold at low prices. The LPG is combusted after being used for refrigeration, and the heat can be used for various processes such as cooking or running an Internal Combustion Engine. This makes LPG an efficient refrigerant in the Non-cyclic Refrigeration system.

Liquefied Petroleum Gas (LPG) as a refrigerant

The environmental effects of refrigerants have been considered recently as most refrigerants are known to be contributing heavily to global warming. "The inert nature of many chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC), particularly CFC-11 and CFC-12, made them preferred choices among refrigerants for many years because of their good thermodynamic properties, non-flammability and non-toxicity. However, their stability in the atmosphere and their corresponding global warming potential and ozone depletion potential raised concerns about their usage. This led to their replacement with hydrofluorocarbons (HFCs), especially R-134a, which have zero ozone-depleting potential and have lesser global warming potentials [7]. However, R-134a still has a high global warming potential of 1300 compared to that of carbon-dioxide which is 1 [8]. Liquefied petroleum gas is a byproduct in petroleum refineries and usually

comprises of 56.4% propane, 24.4% butane and 17.2% isobutene, but the ratios of the mixture may differ slightly from supplier to supplier [9].

LPG is cheaper and it is environmentally friendly having no ozone depletion potential (ODP). It is widely used for cooking purposes. LPG is sold in cylinders of 3.9 kg, 9 kg, 14 kg, 19kg and 48 kg. These cylinders are fitted with valves to control the flow of LPG. Ghariya and Gajjar (2013)[10] stated that, LPG has the following properties:

- It is- Colorless, Odorless (LPG is odorized so that leaks can be detected)
- Heavier than air (this makes it harm if it leaks, as it will displace surround air (oxygen))
- Non-toxic and explosive (which is a disadvantage of using LPG)

Ghariya and Patel (2015)[11] has compared LPG with CFC-12. They performed an experiment to determine the performance of the two refrigerants under different mass charges. Mass charges of 50g, 80g and 100g of the two refrigerants were used. LPG had the highest coefficient of performance (COP) in all the mass charges and was able to maintain the temperature of the evaporator below -5 °C. The temperature of the condenser was kept at a temperature of 47 °C. They also found that at a mass charge of 80g, the LPG refrigeration system had the highest COP.

This study presents a refrigeration system which uses LPG as a refrigerant and LPG is combusted before being released to the atmosphere. The combustion process of LPG gives carbon-dioxide as the byproduct. This makes LPG to have a global warming potential of 1, equal to that of carbon-dioxide. This is a low global warming potential compared to that of R-134a which is 1300. LPG has zero ozone depletion potential, which is one of the desired qualities in a refrigerant.

OBJECTIVES AND SCOPE OF THE STUDY

The main objective of this study is to design and fabricate a low-cost liquefied petroleum gas (LPG) refrigeration system and to study the thermodynamic properties of the system. Thus, developing efficient and cost effective refrigeration systems for rural area in Botswana where there is no electricity [12]. Other motivations are to identify advantages and disadvantages of LPG refrigeration system over other refrigeration systems and to compare the cost and performance of LPG refrigeration systems and other refrigeration systems. This study is useful for both industrial and domestic purposes as it attempts to lower the cost of refrigeration for both domestic and industrial refrigeration systems. This study is especially useful in industries which require refrigeration and heating simultaneously as the LPG refrigeration system designed in this study offers both refrigeration and heating at the same time. Examples of such industries are hotels and restaurants where the LPG used for refrigeration could also be used for cooking and heating water. This refrigeration system could also be useful for refrigeration of perishable goods such as meat and dairy products in transportation trucks. Cost will be highly reduced if they also use LPG as a fuel for locomotion.

LITERATURE REVIEW

A number of researches have been carried out in an attempt to find a refrigerant which has desirable thermodynamic properties and at the same time, being environmentally friendly. Most refrigeration systems use R134a as a refrigerant Propane refrigeration systems have been considered as an alternative refrigeration system to replace current refrigeration systems by Niyaj and Sapali (2017)[13]. They studied the use of propane in domestic refrigerators. Their study is important in developing LPG refrigeration system as propane is one of the components in LPG. The major criteria for their investigation were energy consumption, safety and environmental effect of propane refrigeration system. The results revealed that propane could be used to replace CFC-12, which is one of the commonly used refrigerants. This is because propane consumed less energy than CFC-12 and has zero ozone depletion potential while CFC-12 has ozone depletion potential. Thermodynamic properties of LPG have been investigated by Akash and Said (2009)[14]. They used LPG in a vapor compression refrigeration system and compared it with CFC-12. The results obtained showed that LPG give lower temperatures for equal input of energy for both gases. They also found an alternative refrigerant which could replace CFC-12. These findings are of profound importance as CFC-12 which has high ozone depletion potential could be replaced by refrigerants which have no ozone depletion potential. In an attempt to also find an alternative refrigerant to replace CFC-12, Sattar et al (2007)[15] further conducted an experimental study on the use of isobutene in a domestic refrigerator. Isobutene is one of the constituents of LPG. The results showed that isobutene has a higher coefficient of performance than CFC-12 and HCFC-22 in refrigeration systems. They further stated that, unlike CFC-12 and HCFC-22, isobutene has no ozone depletion potential and also have lower global warming potential (GWP) than the two refrigerants. Sattar et al (2008)[16] investigated experimentally the refrigeration capacity, compressor power and coefficient of performance (COP) to determine the performance of CFC-12 as compared to butane. Butane is present in LPG. The results indicated that butane outperformed CFC-12 in all the criteria listed above. As a consequence of this, LPG should be able to compete successfully against R134a in order to be considered a viable refrigerant. Unlike CFC-12, R134a has zero ozone depletion potential. However R134a has a global warming potential of 1300, which

is why an alternative refrigerant is needed to replace it. Mohanraj et al (2009)[17] investigated if LPG can be used to replace R134a in a domestic refrigerator with a total volume of 0.283 m³.

They performed an experiment to compare the two refrigerants for performance in capillary tubes of varied lengths and varied mass charges. The coefficient of performance (COP) of LPG refrigerator was 7.6% higher (average for different capillary tube length and different charges) than that of R134a. This result shows that LPG is more energy efficient than R134a. Being able to replace R134a with LPG will be a great achievement as R134a has a higher global warming potential than LPG. Austin et al (2012)[18] have also performed an experiment in an attempt to find a refrigerant which could successfully replace R134a as a refrigerant. They compared the performance of R134a to that of a mixture of butane and propane. Their experiment is important in this study as butane and propane are both present in LPG. They found that the power consumption of butane-propane mixture refrigeration system was lower than that of R134a by 4.3%. Also, the COP of butane-propane mixture refrigeration system was higher than that of R134a by 7.6%. Just like Mohanraj et al (2009), they were able to identify a refrigerant which competed successfully against R134a and also have lower global warming potential.

A capillary tube is one of the expansion devices used in refrigeration systems. Javidmand and Zareh (2014)[19] performed an experiment to determine the performance of the capillary tube in a proposition to use LPG as a refrigerant. In their experiment they concluded that, there was an increase in mass flow rate by 106%, when the capillary inner diameter was increased from 1.12mm to 1.52mm. This shows that sizing the capillary tube well is an important aspect in designing the LPG refrigeration system as slight changes in the dimensions of the capillary tube gives a considerably high change in the mass flow rate of the refrigerant. Their study also showed that, when the coil diameter of capillary tube was decreased from 190mm to 70mm, the mass flow rate was decreased by 13%, 7% and 9% for 1.12mm, 1.4mm and 1.52mm inner diameter of capillary tube respectively. These results show that the size of the coil diameter influences the mass flow rate of the refrigerant. However, these results show that the changes are minimal.

Therefore, if the coil can be designed to have a large diameter, the pressure losses and reduction in mass flow rate can be neglected in order to simplify calculation without compromising much on accuracy. Mass flow rate increases with increase in capillary tube inner diameter and coil diameter whereas mass flow rate decreases with increase in length of the capillary tube[20]. Therefore, determining the inner diameter and length of the capillary tube are critical in the design of the capillary tube. The different research, studies and experiments discussed above shows that, refrigerants which have desirable thermodynamic properties and are environmentally friendly could be developed in order to replace the currently used refrigerants. A major problem about the currently used refrigerants is that they have high ozone depletion potential as well as high global warming potential. The above studies have shown that LPG competes successfully against the currently used refrigerant.

MATERIALS AND METHODS

The thermodynamic characteristics of various refrigerants were compared to those of LPG to determine the best refrigerant. However, in this case, important characteristics were considered as no one refrigerant is the best in all characteristics. The performance evaluations of the refrigeration system were performed. The pressure enthalpy chart of LPG was used to determine the performance of the refrigeration system. The refrigeration system performances evaluated in this study are the refrigeration effect of the refrigeration system, the coefficient of performance of the refrigeration system and the refrigeration capacity. The refrigerating effect is evaluated by determining the difference between the enthalpy of LPG at the entrance of the Evaporator and the enthalpy at the exit of the evaporator. The work input was evaluated by determining the energy required to fill the LPG cylinder used in the refrigeration system. An experiment was set-up to determine temperature drop in the evaporator over time. This was done to determine the least temperature reached in the evaporator and how long it was taking for the evaporator to cool.

Design of LPG refrigeration system

LPG is stored in the cylinder at pressure of 12.5 bar. The pressure regulator ensures that LPG is released at a reduced and constant pressure. From the LPG cylinder, LPG is passed through the pressure regulator into the pressure pipe. The pressure pipe is able to withstand a maximum pressure of 100 MPa. From the pressure pipe, LPG is passed through the capillary tube where its pressure is reduced due to the small internal diameter of the capillary tube. The decrease in pressure of LPG results in the decrease in temperature of LPG. From the capillary tube, the low pressure and low temperature LPG is supplied to the evaporator. The evaporator box is constructed using hard board. Hard board is selected for use because of its low cost and its ease to shape and manipulate. Hard board will also contribute to insulation of the evaporator as it has a low thermal conductivity of 0.17 W/m-K. Hard board is shown in brown color in [Fig. 2]. The evaporator box is insulated using polystyrene foam. Polystyrene foam is selected because it has a low thermal conductivity of 0.3 W/m-K as stated by the American Society for Testing and Materials [21]. The thickness of polystyrene foam used is 20mm. Polystyrene foam is shown in white color in [Fig. 2]. In the evaporator, LPG absorbs heat and maintains the temperature of the evaporator below the surrounding temperature. The LPG refrigeration system is set up as shown by the diagram in [Fig. 2] below.

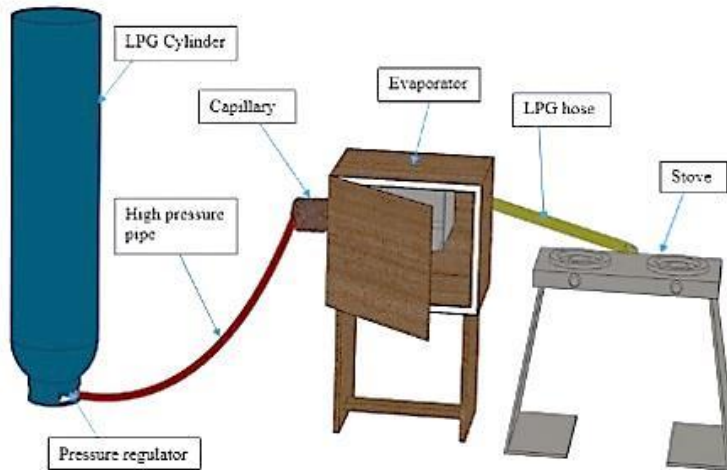


Fig. 2: Setup of the refrigeration system.

From the evaporator, LPG is passed to the gas burner (stove) where it is combusted to produce heat energy. The heat produce can be used for processes such as cooking. Sugumar et al (2015)[22] stated that refrigerant pressure loss increases as the diameter of the capillary tube decreases. This ensures that a shorter capillary can be used and still give the require pressure drop since pressure drop is directly proportional to the length of the capillary tube and indirectly proportional to the internal diameter of the capillary tube as considered by [23]the Darcy-Welsbach equation below from.

$$\Delta P = f \left(\frac{L}{D} \right) \left(\frac{\rho V^2}{2} \right) \tag{1}$$

Where: ΔP is the pressure loss, f is the friction factor, L is the pipe length. Bhatt et al (2011)[24]determined that the maximum mass flow rate required for safe combustion of LPG is 9.52×10^{-4} kg/s. The allowable internal pressure for copper capillary tube is calculated as considered by Bhatt et al (2011)[24] shown in using equation (2)-

$$P = \frac{2S(t-c)}{D-0.8(t-c)} \tag{2}$$

Where: S (maximum allowable stress in tension) = 71.016 MPa, t (wall thickness) = 1.5mm, D (outside diameter) = 3.8mm C (constant for copper tube) = 0 ($C=0$ as cooper has high resistance to corrosion), the allowable pressure of the copper capillary tube is calculated to be 79.6 MPa. Therefore the maximum pressure used in the capillary tube should not exceed 79.6MPa. In the capillary tube, the enthalpy decreases so that the first law of thermodynamics is satisfied, the sum of enthalpy and the kinetic energy must remain constant, as shown by the steady state equation considered by Ram Gopal [25];

$$h_1 + \left(\frac{V_1^2}{2} \right) = h_2 + \left(\frac{V_2^2}{2} \right) \tag{3}$$

Due to the small internal diameter of the capillary tube, the velocity of the fluid increases as it enters the capillary tube. Hence, if the kinetic energy increases the enthalpy must decrease. A mass flow rate which is safe for burning at the stove should be selected. The pressure selected for the LPG refrigerant at the entrance of the capillary tube is 5.7 bars, as it is below the pressure in the LPG cylinder and therefore can be maintained for a long time. The pressure in the LPG cylinder is 12.7 bars[25]. A pressure of 5.7 bars is also safe to be used with the capillary tube as the allowable pressure of the capillary tube is 79.6 MPa as calculated. h_f = enthalpy of saturated liquid = 215.9 kJ/kg. The propane properties table for calculation is used because propane is the most abundant gas in LPG. Furthermore, the properties of propane do not deviate much from the properties of the other two gases present in LPG which are butane and isobutene.

Conservation of mass equation [23] $\dot{m} = \frac{A \times V_1}{v_1} = \frac{A \times V_2}{v_2}$ (5)

Conservation of Energy Equation[23] $1000h_1 + \frac{V_1^2}{2} = 1000h_2 + \frac{V_2^2}{2}$ (6)

The conservation of momentum equation[23] $\left[(p_1 - p_2) - f \left(\frac{\Delta L}{D} \right) \left(\frac{V_m^2}{2v} \right) \right] A = \dot{m}(V_1 - V_2)$ (7)

Mean velocity $V_m = \frac{V_1 + V_2}{2}$ (8)

As the refrigerant flows through the capillary tube, its pressure and saturation temperature progressively drop and the dryness fraction, x , continuously increases[1]. At any point in the capillary tube, the refrigerant properties can be calculated as shown by equations (9), (10) and (11) below.

$$h = h_f(1 - x) + xh_g \tag{9}$$

$$v = v_f(1 - x) + xv_g \tag{10}$$

$$\mu = \mu_f(1 - x) + x\mu \tag{11}$$

The friction factor is determined using the Blasius correlations considered by K.T. Trinh[26]. In Blasius correlation, equation (12) is used to determine the friction factor.

$$f = \frac{0.33}{Re^{0.25}} = \frac{0.33}{\left(\frac{VD}{\mu v}\right)^{0.25}} \tag{12}$$

The mean friction factor applied to the incremental length is calculated as shown in equation (13) below;

$$f_m = \frac{f_1 + f_2}{2} \tag{13}$$

The length of the capillary tube is determined using the analytical method for capillary tube design. The incremental lengths are evaluated for a change in temperature of 1°C. Combination of equation (5) and (6) gives equation (14) below:

$$1000h_2 + \left(\frac{v_2^2}{2}\right)\left(\frac{\dot{m}}{A}\right)^2 = 1000h_1 + \frac{v_1^2}{2} \tag{14}$$

Substituting equation (9) and (10) into (14) gives equation (15).

$$1000h_{f2} + 1000(h_{g2} - h_{f2})x + \left[\{v_{f2} + (v_{g2} - v_{f2})x\}^2 \left(\frac{\dot{m}}{A}\right)^2 \right] = 1000 h_1 + \frac{v_1^2}{2} \tag{15}$$

The incremental length, ΔL, is calculated below considered by Bhatt et al [24]:

$$\Delta L = \frac{(P_2 - P_1) - G(V_2 - V_1)}{\left(\frac{G}{2D}\right)(f_m)(V_m)} \tag{16}$$

Where: The mass velocity, $G = \frac{4\dot{m}}{\pi D^2}$ (17)

The iterations for the incremental length, ΔL, were performed up to a pressure of 2 bars. This pressure gives a desirable temperature of -25°C (from LPG property tables) and a dryness fraction, x, of 0.38. The length of the capillary tube at this pressure is 2.93m. Properties of LPG at 2.0 bars are:

- h_f = enthalpy of saturated liquid = 139.5 kJ/kg
- h_g = enthalpy of saturated vapour = 546.2 kJ/kg
- v_f = specific volume of saturated liquid = 0.00177 m³/kg
- v_g = specific volume of saturated vapour = 0.220 m³/kg

Heat transfer coefficient of the evaporator as considered by [27], $U = \frac{1}{\frac{L_p}{K_p} + \frac{L_h}{K_h}} = 1.425 \text{ W/m}^2\text{K}$

Total Thermal resistance, $R_t = \frac{1}{AU} = \frac{1}{1.0442 \times 1.425} = 0.672 \text{ W/K}$

The refrigerating effect is evaluated by determining the difference between the enthalpy of LPG at the entrance of the Evaporator and the enthalpy at the exit of the evaporator. The properties of LPG in the evaporator are evaluated at a pressure of 2.0 bars. The properties of LPG at pressure of 2.0 bars evaluated are as shown below:

- $h_f = 139.5 \text{ kJ/kg}$, $h_g = 546.2 \text{ kJ/kg}$, $h_{fg} = 406.7 \text{ kJ/kg}$, Saturation Temperature, $T_2 = -25^\circ\text{C}$

The enthalpy of LPG at the entrance of the evaporator, $h_2 = h_f + xh_{fg} = 294.0 \text{ kJ/kg}$. It is assumed that the refrigerant leaves the evaporator as a dry vapour as it happens in an ideal refrigeration cycle. In this case, properties of LPG at the exit of the evaporator are equal to those of dry vapour LPG at a pressure of 2.0 bars. From the diagram, $h_3 = h_g = 546.2 \text{ kJ/kg}$. Where h_3 is the enthalpy of LPG at the exit of the evaporator. Therefore, the refrigeration effect is, $h_3 - h_2 = 546.2 - 294.0 = 252.2 \text{ KJ/Kg}$

Where: h_2 is the enthalpy at the entrance of the evaporator and h_3 is enthalpy at the exit of the evaporator as shown in [Fig. 3] below.

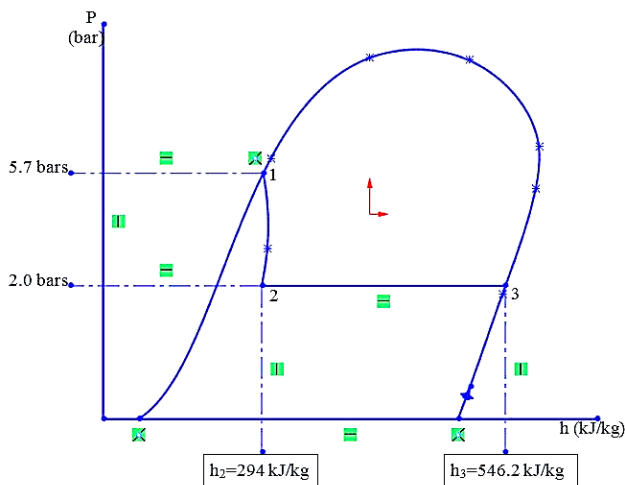


Fig. 3: The p-h diagram of refrigeration system.

Refrigeration capacity = $\dot{m} (h_3 - h_2) = 9.52 \times 10^{-4} (546.2 - 294.0) = 240 \text{ W}$. In order to determine the coefficient of performance (COP), the work input of the refrigeration system should be determined. The work input has to be determined when evaluating the COP. Sathayanet al (2018) [28] calculated the work required to fill 1kg of LPG in a cylinder to be 77.832 kJ.

Therefore, the coefficient of performance (COP) is calculated as shown below.

$$COP = \frac{\text{Refrigeration effect}}{\text{Work Input}} = \frac{h_3 - h_2}{W} = \frac{252.2}{77.832} = 3.24$$

RESULTS AND DISCUSSION

An effective refrigeration system should be able to reach low temperatures in a short period of time. An experiment was set up in order to determine how effective the LPG refrigeration system designed is. In this experiment, a thermocouple thermometer was used to measure the temperature in the evaporator at time intervals of 5 minutes. The experiment was carried out over a time of 100 minutes. In this experiment, the temperature was taken in two sections of the evaporator which are the freezing section and the non-freezing section, as shown in [Fig. 4]. The freezing section is inside the tube and plate heat exchanger while the non-freezing section is outside the heat exchanger.

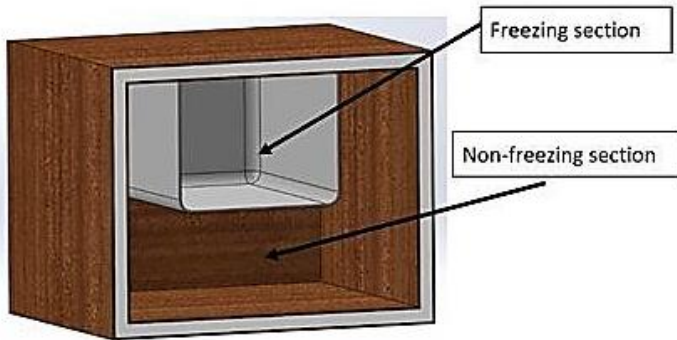


Fig. 4: Evaporator (shown without the door).

[Table 1] and [Table 2] below shows the temperature of the freezing section and non-freezing section of the evaporator over a time of 100 minutes at 5 minutes time intervals respectively. A graphical representation of the temperature variation is shown in [Fig. 5] below.

Table 1: Temperature in the freezing Section of the evaporator with time

S.N.	Time(min)	Temp(°C)	S.N.	Time(min)	Temp(°C)	S.N.	Time(min)	Temp(°C)
1	0	27.2	8	35	-3	15	70	-11
2	5	14.1	9	40	-5	16	75	-11
3	10	3	10	45	-5	17	80	-11
4	15	1	11	50	-5	18	85	-12
5	20	-1	12	55	-7	19	90	-12
6	25	-1	13	60	-9	20	95	-13
7	30	-2	14	65	-10	21	100	-13

Table 2: Temperature in the non-freezing section of the evaporator with time

S.N.	Time(min)	Temp(°C)	S.N.	Time(min)	Temp(°C)	S.N.	Time(min)	Temp(°C)
1	0	27.2	8	35	12.5	15	70	5.3
2	5	24.3	9	40	11.2	16	75	5
3	10	19.4	10	45	10.1	17	80	4.4
4	15	17.1	11	50	10.1	18	85	3.7
5	20	15.7	12	55	7.6	19	90	3.3
6	25	14.9	13	60	6.7	20	95	3
7	30	13.9	14	65	5.8	21	100	3

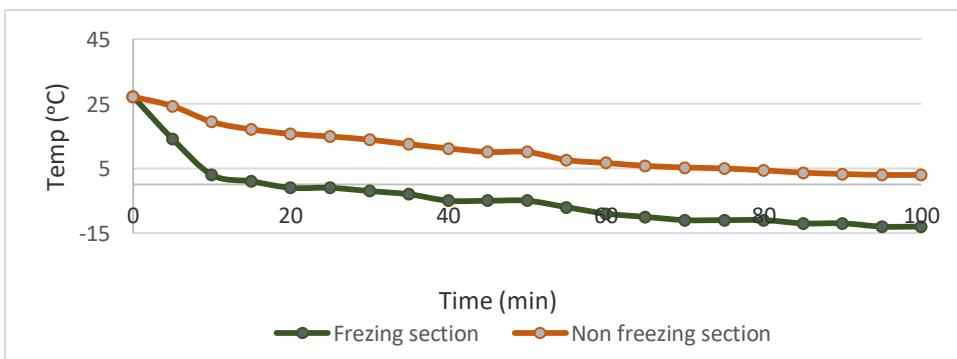


Fig. 5: the temperature distribution in the evaporator over time.

The results of the experiment show that LPG refrigeration system designed in this study is an effective refrigeration system as low temperatures were reached in the evaporator and maintained well. The graph in [Fig. 5] above shows the temperatures to be decreasing in a logarithmic fashion. This due to the fact that the temperature difference between the refrigerant and the evaporator decreases over time.

According to Akintunde (2013) [29], Domestic refrigerators which utilize R134a as a refrigerant have a coefficient of performance (COP) of 2.03 and give an evaporator temperature of -5°C . This shows that the performance of LPG refrigeration system is impressive as it gave a minimum temperature of -13°C having a COP of 3.24. These are important results considering that LPG is more environmentally friendly than R134a as it has a lower global warming potential than R134a. He also performed an experiment to improve the performance of R134a by making a 50:50 blend of R134a and R600a. This new refrigerant had a coefficient of performance (COP) of 2.30 and still gave an evaporator temperature of -5°C .

LPG as refrigerant, still outperforms this refrigerant in both the evaporator temperature and coefficient of performance. These results show that LPG can be used to substitute R134a as a refrigerant as it is more environmentally friendly and performs better than R134a in refrigeration systems.

CONCLUSION AND RECOMMENDATIONS

The study has given satisfactory results and shown that a low-cost refrigeration system can be fabricated using LPG as the total cost of components required to fabricate the refrigerator is P850.00, excluding the experimental setup costs. This refrigeration system also has low running costs as it has no moving parts and therefore requires less maintenance as compared to refrigeration systems which use compressors. The LPG refrigeration system designed in this study gives a coefficient of performance (COP) of 3.24 which is higher than that of domestic refrigeration systems using R134a as a refrigerant, as they give COP of 2.03. This study has also shown that LPG can successfully replace R134a in refrigeration systems as it has a higher coefficient of performance and gives lower temperatures. This study has shown that an efficient refrigeration system which is environmentally friendly and has low cost can be achieved using LPG as a refrigerant. The authors would recommend the LPG refrigeration system presented in this study should be studied further with the aim of popularizing LPG refrigeration system so that it can be used more, in homes and industries. This will help in reducing the increase global warming as LPG is an environmentally friendly refrigerant. This will also help in the electric energy crisis which persists across the world as the refrigeration system presented in this report does not require the use of electric energy. The authors also recommend that in a situation where heating is not required continuously, a compressor and a condenser should be designed and added in the refrigeration system. This will ensure that when heating is not required at a certain time, LPG will be re-circulated in the system, and only be released to the gas burner when heating is required.

CONFLICT OF INTEREST

None

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FINANCIAL DISCLOSURE

None

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ARTICLE

AN MMIC LOW-NOISE AMPLIFIER DESIGN TECHNIQUE

Ayush Kumar, Tamal Majumder*, Prakash Kumar Tiwari, Ritvik Vaid, Priyanka Bansal

Department of Electronics and Communication Engineering, Manav Rachna International Institute of Research and Studies, Faridabad, Haryana, INDIA

ABSTRACT



Low Noise Amplifier (LNA) is one of the most important components for today's communication systems. Lot of millimeter-wave application devices such as receivers; Trans receivers can't be imagined without LNA nowadays. As, it is necessary to suppress the noise interference within the signal for efficient communication and amplifiers are always used for enhancing the strength of the signal in order to cover the long distance communication. Therefore the use of LNA is highly necessary to improve the quality of communication. This paper made a brief attempt to present the design discussion of LAN's and its usability along with the application areas. The various technologies used for the manufacture of LNA and its progressive aspects are also discussed. Some major findings are also highlighted in the same area such as CMOS Broadband Low-Noise Mixer with Noise Cancellation, Noise Adaptive Channel Smoothing of Low-Dose Images

INTRODUCTION

KEY WORDS

LNA, Two finger technique, On-wafer technique, MMIC technique, packaged amplifier

Increasing Low noise amplifiers are important components in mm-wave application such as radio astronomy, receivers for communication system, earth science radiometry, passive remote sensing and transceivers for radar instruments [1]. The invention of Inp HEMT, metamorphic HEMT, and InP HBT devices have enabled amplifiers to operate at exceptionally high frequency. Cryogenically cooling of HEMT amplifiers effectively reduce the noise level in very large amount [2]. Along with it is also used to improve the sensitivity of radiometers of astrophysics and earth observation instruments. Recently cryogenic result of 35-nm InP HEMT monolithic microwave integrated circuit have led to record noise above 100GHz [3]. Although the continuous research on this technology offer to design amplifiers at highest frequencies and with minimum noise temperature. There are several challenges faced by designers in the pathway; such as lower breakdown voltage and maximum high frequency of oscillation of the transistors. Due to these issues, a stable amplifier to fulfill the linearity of a wideband receiver, which requires high gain from LNA system, is very difficult to design [4]. The aim of this paper is to examine and finding the solution in order to take full advantage of the available latest technology.

The first design of three stages LNA is implemented at Northrop Grumman Corporation's, (country name and year). This design is implemented using 35-nm InP MMIC technology on InAs composite channel (IACC) HEMTs, which produced 23-K noise temperature at 108 GHz, when cooled cryogenically at 27 K[5]. This manufacturing process follows a fixed design procedure of MMIC LNA, where an appropriate gate width for the device is achieved by placing number of fingers in parallel manner within a single transistor to produce the lowest level of noise above 100 GHz along with possessing wide bandwidth and better linearity. While, designing wide band cryogenic LNAs, the design approach have some limitations especially regarding the stability of the amplifier. Therefore, a new parallel two-finger unit transistor MMIC LNA design technique is introduced [6], which enables the design of wideband, high linearity, and first-time-right LNAs with very stable, predictable, and repeatable operation at cryogenic temperatures.

The first design cycle amplifier based on this design approach achieve more than 20 dB gain over the range of 75 GHz to 116 GHz frequencies and produced 26 to 33 K noise temperature with high stability as compare to the conventional amplifier. Later, a new method is proposed to predict the stability of a multi-finger transistor using two-finger transistor model [7]. This method also verified the hypothesis i.e. "odd-mode or loop oscillations can occur within a multi-finger transistor is due to the asymmetry of the transistor [8].

The paper presented here, is organized as follows. At first, fundamentals of selecting a proper device size for a LNA is discussed and followed by the design of a conventional multi-finger HEMT amplifier. After that the MMIC LNA design technique is introduced followed by On-wafer and package amplifier design approach

THE SELECTION OF AN APPROPRIATE SIZE FOR THE DEVICE

The selection of the appropriate size transistor is the most crucial part of the amplifier designing. For keeping the miniature size, at first select an optimized width of gate and design a single finger. Now with the help of these fingers, the full transistor is designed [9]. The gain and the noise parameters of the transistor designed through this technique are not affected significantly by the number of fingers. These numbers are only responsible for producing a small change which is due to the distributed effects of connecting wires [10]. These numbers are contributing their effects in device impedance and power capability. While designing the High Electron Mobility Transistor, this technique plays an important role to optimize it. As the HEMT is start operating from very high frequency (approximately 2 GHz) and at this high

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*Corresponding Author
Email:
tamal.mriu@gmail.com

level of frequency there is huge chances of generating high noise [11]. Therefore it is challenging task for the researcher to design HEMT with low sound temperature along with lower break down voltages. In this technique, the gate is designed with very low resistance, which contributes its effect to reduce the noise. It also helps to enhance the gain value of the transistor [12].

STUDY OF MULTI-FINGER HEMT INSTABILITIES

Two finger transistors are symmetrical in architecture. In this transistor, drain is in the middle position and the sources are present at both side of the drain. However, the HEMT transistor more than two fingers also having the sandwich structure with drain and sources, keeping drain in the middle but here the drains and sources are connected. Due to these internal connections, the parasitic impedance of the HEMT structure increases, which deviates it from the ideal structure, which makes the cryogenic modeling of this transistor is very important. Apart from this to predict the stability of this transistor is also very challenging due to its higher frequency up to 1 THz. Again the transconductance and the frequency value rises considerably higher at cryogenic temperatures, which again influence the stability factor of this transistor [8]. Again, due to the asymmetry present in its structure, the phenomenon of loop oscillation is developed, which again decrease its stability at high frequencies. This developed loop oscillation affects the drain current and enhance it drastically. Due to this jump in drain current, the net gain of this transistor decreases and the noise temperature increases up to the 10-20 K. To cope up with these instabilities arises in four finger transistor, the model is suggested, which developed the targeted amplifier using two finger transistors only. According to this model, at first the four finger transistor is developed using two finger transistor and the air-bridges present in the structure are modeled using inductors having value 10 pH. The amplifier made up using this model, having showing better performance as compared to the previous one [11].

NEW PARALLEL TWO FINGER TRANSISTOR LNA DESIGN TECHNIQUE

This technique is also focuses towards the instability issues arises in the multi-finger transistor. This method is proposed by Yang in 2013 [13]. According to this model, at first a two finger transistor is optimized for the desired frequency using T_{casmin} technique. The impedance is designed through the number of unit cells and these cells also control the output power. Once the numbers of unit cells are selected according to the requirement of the application, it is fed in parallel wise manner with the help of matching networks and power division sections [14]. Now using these two finger transistors, multi-finger transistor are constructed. Due to use of unit cells for designing, the scalability of the multi-finger transistor increases. It also helps to reduce the complicity of routing network. In this way, this model avoids the stability issues of multi-finger transistor and also provides better control over the linearity of the amplifier [15]. Though, due to the presence of matching and power division network, this model having higher losses at the input side.

DESIGN OF AN LNA USING THE PARALLEL TWO-FINGER UNIT TRANSISTOR

In various designing techniques, it is observed that the utilization of a multi finger transistor produced oscillations that occur within the transistor [16]. As to overcome from this stability issue, this method dedicated to divide the four finger transistor into two finger transistors with same input and output conditions. For designing this, at first the low-impedance transmission line is used in series wise manner for matching the input and output. This transmission line is also used for power dividing and combining purpose. If this layout is not properly designed then three different types of oscillation will initiated named as even mode oscillation, odd mode oscillation and hypothesized mode oscillation. The even mode oscillation is similar as the oscillation produced in conventional amplifier using four finger devices [17]. The odd mode oscillations occur due to the on chip dividing and combining process. The hypothesized mode oscillation problem occurs within the single finger transistor. Hence, this method is simpler in design and produces circuit with enhance stability along with excellent performance [18].

MMIC Amplifier Technology

MMIC stands for monolithic microwave integrated circuit. The word monolithic is derived from the Greek letter "Monos (single)" and "Lithios (stone)". Thus, these circuits are built on a single crystal. MMIC amplifiers are a type of integrated circuit device that operates at microwave frequencies (300 MHz to 300 GHz). This device typically performs function such as microwave mixing, power amplification, low noise amplification and high frequency switching [19]. It posses high dielectric constant (9 or higher) and low dissipation factor or loss tangent. The permittivity of MMICs should be remains constant over the entire temperature range of interest. The major features of MMICs are having high purity, constant thickness, high surface smoothness, high resistivity, high thermal conductivity and dielectric strength, which make them easier to use as cascading. Again it does not require any external matching network, while cascading. MMIC are generally fabricated using Gallium Arsenide and A III-V compound semiconductors [20]. The metal oxide semiconductor field effect transistors (MOSFETs) are used as the active device in MMIC amplifier. However, recently high electron mobility transistors (HEMTs), pseudomorphic HEMTs and

heterojunction bipolar transistors become more prominent replacement as the active device in MMIC amplifier. The [Table 1], shown below highlights some previous work done on MMIC amplifier technology.

Table 1: Notable Previous work on MMIC Amplifier Technology

S.no	Author	Objective	Advantages	Limitations	Reference
1.	Bo Chen et. al.	To design a broadband MMIC low noise amplifier	<ol style="list-style-type: none"> 1. A 2dB noise figure from 25 GHz to 40 GHz is achieved. 2. Less noise figure is obtained 	<ol style="list-style-type: none"> 1. Signal gain is small 2. Sensitive to the resistance of matching network. 	[21]
2.	Dongsu Kim et. al.	To develop a Compact and Low-profile GaN Power Amplifier Using Interposer-based MMIC Technology.	<ol style="list-style-type: none"> 1. Capable to integrate heterogeneous IC's 2. Compatible with various microwave and millimetre-wave systems. 3. Having high degree of design flexibility. 4. Low cost. 	<ol style="list-style-type: none"> 1. It can't be realised using a single MMIC technology. 	[22]
3.	YounSub Noh et. al.	For using Ka-band GaN Power Amplifier MMIC Chipset for Satellite and 5G Cellular Communications	<ol style="list-style-type: none"> 1. Increased in gain. 2. Increased in efficiency. 3. Compact in size. 	<ol style="list-style-type: none"> 1. Having return loss at same frequency. 2. Complex design. 	[23]
4.	K. Tsukashima et. al.	To develop transceiver MMIC's for Street Surveillance Radar	<ol style="list-style-type: none"> 1. Miniature chip size. 2. It can be directly flip-chip on assembled board. 	<ol style="list-style-type: none"> 1. Performance is varied with temperature. 2. Complex design 	[24]
5.	Amin Ezzeddine et. al.	To develop broadband MMIC Power Amplifier for multiple wireless systems	<ol style="list-style-type: none"> 1. Low cost production. 2. It has good linearity and high power density 3. Achieved good efficiency and o/p power. 	<ol style="list-style-type: none"> 1. High ohmic loss. 	[25]
6	W. Simburger et. al.	To develop 1.3W 1.9GHz and 1W 2.4GHz power amplifier MMIC in silicon	<ol style="list-style-type: none"> 1. It is very low cost power amplifier. 2. High output power 3. Good input impedance matching 4. Power efficiency is high 	<ol style="list-style-type: none"> 1. Large amount of current are loss. 	[26]
7	Shigeo KAWASAKI et. al.	To develop a High-gain and Low-Noise MMI Amplifier Module for Ku-Band antenna.	<ol style="list-style-type: none"> 1. Low noise 2. Compact in sized 3. Cost is low 	<ol style="list-style-type: none"> 1. Return loss is high 	[27]
8	Diana Zhang et. al.	To develop a Novel GaAs Multi-Chip MMIC Video Amplifier for Optical Receiver in cable Communication systems	<ol style="list-style-type: none"> 1. Receiver gain is high. 2. Having wide optical dynamic range. 3. High sensitivity and linearity. 4. Low power consumption. 	<ol style="list-style-type: none"> 1. High RF output over weak input optical signal. 2. Having high input impedance. 3. Uses very expensive coaxial cables. 	[28]
9	A. Leather et. al.	To develop 50nm sized MMIC amplifier for 480GHz	<ol style="list-style-type: none"> 1. Cost effective 2. Highly robust and process yield 3. Compact design 	<ol style="list-style-type: none"> 1. Working at low frequency only 	[29]
10	Yeoung chang chou et. al.	To manufacture a reliable 0.1um AISb/InAs HEMT MMIC Technology for ultra low power application	<ol style="list-style-type: none"> 1. Consume less power 2. Reduced noise 3. High speed 4. High performance 	<ol style="list-style-type: none"> 1. Costly 	[30]

On-Wafer Measurement

Nowadays, microwave wafer probing measurement technique is accepted and applied worldwide as one of the efficient techniques in microwave IC development. The major attraction of this method is its resolution and

repeatability of calibrations which is possible at the probe tips along with it is very convenient and having high throughput [31]. This *measurement method is used to determine S-parameter of On Wafer active devices* in between from 500MHz to 40 GHz [32]. This measurement technique required some fixed fixtures (electrical as well as mechanical) such as wide bandwidth transmission, low contact of resistance, consistent probe shape, placement of probe, durability etc. Microwave probe transmission line contact precisely with the impedance right to the ground-signal-ground-contact. For the measurement procedure, at first turn on the equipment approximately one or two hours before calibration has done. Take care that the probe, which is mounted at 150um and set all dc voltage to zero, ensures that the probes are in place. The cables need to be clean and tight and the torque will be using relevant wrench IPA along with the clean and dry connectors. The probe tips are inspected and clean if it is contaminated. The positioner planarity is adjusted until all tips make even contact with the substrate. Now, set the basic parameters for the measurement such as frequency range, power level, type of sweep etc. and get the required data of measurement. The table given below [Table 2] represents the advantages and limitations of some previous works on On-Wafer measurement technique.

Table 2: Notable Previous work on On-Wafer Measurement Technique

S.no	Author	Objective	Advantage	Limitations	Reference
1.	G. Dambrine et. al.	To measure on-wafer high frequency noise of FET's	<ol style="list-style-type: none"> 1) Automatic tuner is not required 2) Easy to develop on conventional microwave probe wafer system 3) The modification of input admittance is performed near the device. 	<ol style="list-style-type: none"> 1) Required calculations are complicated. 	[33]
2.	Chen Liu et. al.	on-wafer measurements using 10-term error model	<ol style="list-style-type: none"> 1) Better than conventional SLOT method. 2) Improved measurement accuracy. 	<ol style="list-style-type: none"> 1) Probe coupling should be corrected. 2) More difficult to characterize. 	[34]
3.	Ryo Sakamaki et. al.	To improve the on-wafer measurement accuracy at millimetre-wave frequencies	<ol style="list-style-type: none"> 1) Improvement in verification process. 2) A precise s-parameter measurement is realised 	<ol style="list-style-type: none"> 1) Probe positional variation is limited by optical wavelength. 2) Required more skilled person for measurement 	[35]
4.	Aihua Wu et. al.	To develop a Verification Technique for On-wafer Noise Figure Measurement Systems	<ol style="list-style-type: none"> 1) The measured NFs have a good agreement with the references for both the 1 dB and 3 dB attenuators as-long-as the effect of bondwire is removed. 	<ol style="list-style-type: none"> 1) The cascaded network consists of a mismatched attenuator and a LNA. 2) The measured NFs are not related to the injected noise signal but strongly dependent on source match. 3) Not capable to verify the noise measurement system. 	[36]
5.	Luuk F. Tiemeijer et. al.	To characterize On-Wafer Noise-Figure	<ol style="list-style-type: none"> 1) Able to measure the differential noise figure 2) Not affected by the common mode port terminations. 	<ol style="list-style-type: none"> 1) At 60 GHz, the path difference between the balun and device- under-test (DUT) must be less than 70 m, to keep the phase error below 5°. 	[37]
6.	Inder Bahl et. al.	Automatic Testing of MMIC Wafer	<ol style="list-style-type: none"> 1) Achieved good accuracy at maximum operating frequency. 2) Achieved good dimension. 	<ol style="list-style-type: none"> 1) Calibration is highly required by skilled person 2) Unit and Probe change/degradation will highly affect the results 	[38]
7.	Takuya Imamoto et. al.	To reduce the low-frequency noise in	<ol style="list-style-type: none"> 1) Off-leakage current is reduced 	<ol style="list-style-type: none"> 1) The performance of 	[39]

		vertical MOSFETs	2) Consume less time 3) Low cost	the circuit is decreases due to the elimination of back bias	
8.	Christopher T. Coen et. al.	To design and characterized G-Band SiGe HBT Low-Noise Amplifiers	1) Improved gain performance.	1) High noise 2) Integration capabilities are low	[40]
9.	Troels Emil Kolding et. Al.	To establish a new method (Four-Step Method) for De-Embedding Gigahertz On-Wafer CMOS Measurements	1) The extraction method is very strong. 2) It accurately predicts the series losses.	1) Higher numerical complexity than conventional CBD method. 2) Not fully comfortable with specified layout guidelines.	[41]
10.	David E. Bockelman et. al.	To measure the Mixed-Mode S-Parameters of Differential Circuits using Pure-Mode Network Analyzer	1) More accurate 2) Less numerically complex 3) It has ability to generate simulated mixed-mode - parameters from CAD.	1) Difficult to make pure mode system. 2) Having residual errors in calibration. 3) Metal and dielectric losses are present	[42]

Packaged Amplifier Technology

Packaged amplifier is strongly depends upon the operating frequency. In this amplifier to achieve the high accuracy and maximum power transmission, a matching network is required on the input and output to minimize the reflection problems [5,10]. It is of very low cost and compact in size. The major advantage of packaged amplifier is its ability to work on both (AC and DC) power supply and gives high performance over the wide frequency range. Again, it includes current limiter circuit for failure protection purpose due to the over heat [6]. The [Table 3], shown below highlights some previous work done on Packaged amplifier technology.

Table 3: Notable Previous work on Packaged Amplifier Technique

S.no	Author	Objective	Advantage	Limitations	Reference
1.	Abdul R Qureshi et. al.	To develop the more efficient RF power amplifiers	1. Energy efficiency is high. 2. The power combining networks is simple and compact. 3. Having high data rate for mobile communication	1. Cost is high 3. Having more complex modulation system	[43]
2.	Maciej Myslinski et. al.	To establish a large signal Behavioral Model for Packaged RF Amplifier		1. Very high cost. 2. Heavy weight. 3. Having higher harmonics	[44]
3.	Gary (Guohao) Zhang et. al.	To develop a linear amplifier architecture and its packaging technologies for new generation smart phone applications.	1. Low cost. 2. Compact in size and good performance 3. Having high efficiency at low power. 4. Good thermal dissipation.	1. Load sensitivity is low.	[45]
4.	Kris kong et. al.	To develop a compact 30 GHz MMIC High Power Amplifier	1. Output power performance is high.	1. Expansive product 2. Having small signal response.	[46]
5.	Jiajie Tanga,b, Huajiang Wang,a et. al.	An MCM Package Process for 24GHz Driver Amplifier Using Photosensitive BCB	1. Higher density. 2. better performance 3. higher reliability 4. low cost 5. MCM is one of the important steps of 3-dimensional High Density Packaging.	1. The interlayer-connection resistance is 75mΩ which is not as good as that of the MCM manufactured with dry-etch BCB.	[47]
6.	Plextek RF I	To develop 5W X-	1)GaN(Galium	1) It produces high	[48]

		Band GaN Power amplifier using discrete plastic packaged SMT transistor	Nitride) discrete transistor is readily available. 2) Low cost. 3) Easy to handle. 4) High stability at frequency above 12.5GHz.	thermal noise. 2) Efficiency is low.	
7.	Jong-Min Lee et. al.	To develop wideband transimpedance amplifier	1)Wideband transimpedance amplifier 2) Quality of voltage signal is high. 3) Performance is good	1)Highly complex circuit design. 2) Power loss due to high transimpedance	[49]
8.	Dusan N. Gurjic et. al.	To estimate the power amplifier package model using sweep measurement	1)it has very high frequency range operability 2)it has wideband frequency response 3) Power output is maximum	1) Expensive and complex 2) Difficult to construct	[50]
9.	Kris Kong et. al.	To develop a compact MMIC high power amplifier in chip for 30GHz	1)Low cost 2)High gain 3)Output power performance is high	1)Low impedance transmission 2) Condition specific	[51]
10.	Ravi Gugulothu, Sangam Bhalke et. al.	To characterized GaAs MMIC C-Band amplifier	1)Produces good gain and 2)Output power is high	1)Expensive 2)Condition specific	[52]

CONCLUSIONS

At present scenario, the multi-finger transistors are one of the necessary devices in order to perform several required applications, which are of human need and make our life easier. It was also verified that oscillations can occur with-in a multi-finger transistor and it works on high frequency that design to analyze frequency of that amplifier. These oscillations are not in favor of the stability of that transistor or making adverse effect on the stability of the entire amplifier. Therefore, it is highly necessary to prevent these effects. More precious, the technique is predicting for the stability of a multi-finger transistor using a two-finger transistor model is discussed. The oscillation is inferred by the using of dc measurements. These types of instabilities limit give the opportunity for choosing the appropriate device impedance and also the output power capacity of that transistor. Through overcome from stability problem of multi-finger transistors; design a parallel two-finger unit transistor MMIC LNA design technique that gives the full benefit of latest sub-50-nm HEMT technology. The design which is based on this design approach and it achieves better result comparable to the W-band cryogenic amplifiers. This shows that the new design approach is attractive for the design of LNA because it gives high gain and linearity which is very useful in design wide-band receiver system. Again it will be applied to reduce the noise figures and improve the gain. There is also work needed for the enhancing the bandwidth and linearity. Also the frequency application range is needed to be increase on and above 100 GHz in order to fulfill various application lie in a future need.

CONFLICT OF INTEREST

None

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ARTICLE

A REVIEW ON THE REFRIGERATION SYSTEM POWERED BY PHOTOVOLTAIC (PV) ENERGY

Dinesh Chawla, Anil Jat, Rahul Garjola*, Subham Srivastava, Kunwar Kaushal, Kevin Varghese

Department of Mechanical Engineering, Manav Rachna International Institute of Research and Studies, Faridabad, Haryana, INDIA

ABSTRACT

Limited availability and pollution-prone tendency of traditional energy resources have encouraged the utilization of unconventional or renewable energy resources in daily use technology. The refrigeration process is an essential process which preserves the food, beverages, vaccines, lifesaving drugs and daily essentials for a longer duration of time. Irregular power supply and higher power cost significantly affect the efficiency of a refrigerator. The development of renewable energy powered refrigerators can be a reliable solution to this problem. This paper reviewed the development of solar powered refrigerators. Here, special attention has been paid on the performance and functioning of various configurations of photovoltaic energy powered refrigerators. In some refrigerators, solar energy (DC) obtained from PV panels was used directly by using DC motor, while in some cases it was transformed into an AC by using an inverter. In the maximum studies, it was found that a home refrigeration system irrespective of any configuration can be run successfully using solar energy. The factors like high installation cost, low conversion capability of PV modules, and poor energy accumulation and holding capacity of batteries played a major role in not being utilized this technology in everyday life. It is expected that the use of next generation miniaturized and efficient electronic components especially solar cells and batteries in the refrigeration system would bring a boom in this segment.

INTRODUCTION

KEY WORDS
Solar energy,
Refrigeration,
Photovoltaic effect,
Pollution; Battery

Recently particular emphasis is being given on the production of renewable energy-driven appliances owing to increasing awareness and concerns about the environment. Among various renewable energy resources, solar energy is the most popular one and abundantly available on earth. There are considerable research initiatives worldwide, especially on the development of solar-powered equipment. A solar panel consists of silicon solar cells directly interact with sunshine and convert it into the electrical current as per photovoltaic (PV) effect. The ability to convert solar energy into usable electricity is usually presented as the efficiency of the solar panel. With continuous research efforts, the efficiency of a solar panel has been increased by almost 23%. Even today, the maximum efficiency of commercially available solar panels lies in between 15-18%. Over the last few decades, the problem of heat in many portions of the world is taking a perplexing form due to excessive global warming. This problem becomes even more distraught when energy production from conventional energy resources is low, and the power supply is irregular. Solar energy is capable of ceasing the electricity shortage problem if utilized on its maximum capacity. Considering this fact, extensive research is being conducted to increase the potential of solar panels across the globe. A considerable amount of energy is consumed in various types of refrigeration systems. Vehicles transporting milk products, fruits, vegetables, medicines, vaccines etc. are usually equipped with small cooling equipment. In addition to that, most of the luxury vehicles, caravans, boats, cars, etc. are also often equipped with small air conditioning units. For such applications, low capacity compressors are employed which operate on direct current (DC) and a small voltage (i.e. 12-24 V). Renewable energy systems, especially solar panels, also generate electrical energy in the form of DC voltage or current. For the storage of life-saving drugs, vaccines and food items, a solar-powered refrigeration system can be considered the most optimal. The photovoltaic (PV) refrigeration system has been in existence for quite some time, but its use is limited to some specific applications only. The main reason for this is that the cooling capacity of the PV-operated (DC) cooling system is less than that of the alternate current (AC) driven cooling system. Compared to AC powered compressors, DC powered compressors come in small sizes and are able to cool the small area only.

In this article, a comprehensive review of PV driven cooling systems and their development has been presented. The effectiveness of this system and the effect of various parameters on its performance have also been documented.

PV POWERED COOLING SYSTEMS

A PV cooling system is made up of components like PV arrays, batteries, invertors, vapor compression refrigeration systems etc. This system can be classified into DC or AC cooling systems. A schematic diagram of a typical PV operated DC refrigeration system is shown in [Fig.1]. PV powered AC cooling system consists of an additional component named inverter to convert direct current to alternating current. In some PV powered refrigeration systems, additional energy generators in synchronization with the primary energy source are also employed to ensure uninterrupted power supply. De Blas et al. [1] designed a PV operated refrigeration system to preserve milk. On analyzing the performance of this system, they found that better performance of the system was mainly depended on the solar radiation level, motor speed and voltage required to run the motor. In this arrangement, two concentric vessels were used in which frozen

*Corresponding Author
Email:
garjolarahul@gmail.com
Tel.: +91 7838657487

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water stored in the external container and milk in the inner container. Here, solar energy was collected in the form of latent heat of frozen water, and milk was kept at 4 °C. The Coefficient of Performance (COP) of the system was enhanced when condenser and electric motors were kept outside the refrigeration chamber. In another study, De Blas et al. [2] evaluated the operation of the PV system powered DC motor required for refrigeration in various motor parameters. They prepared graphs to determine the optimum operating parameters to achieve the best electromechanical properties and extract maximum COP from the refrigeration system. Del Pero et al. [3] checked the feasibility of a PV powered refrigerator for food conservation in rural areas. In their energy model, they claimed that the electrical power obtained from the PV module was higher than the power required to operate the compressor. According to them, this model is very economical and can be easily manufactured using locally available low-cost materials. Del Pero et al. [4], in another study, tested a PV powered refrigerator kit in a climate condition of Cameroon village.

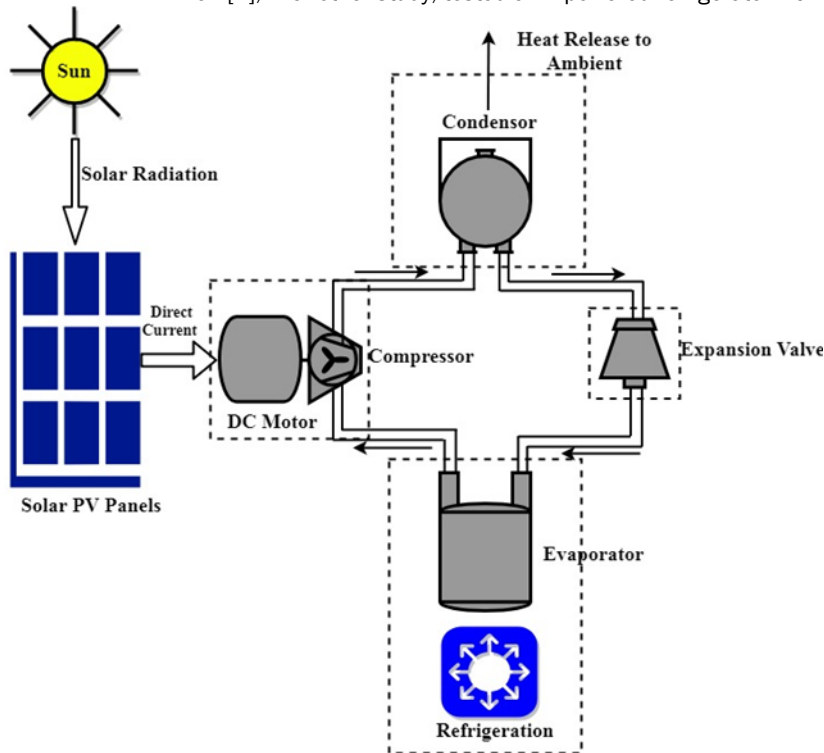


Fig. 1: Schematic diagram of solar PV refrigeration.

They found a 250 L refrigerator could be maintained at or below 10 °C for approximately 48 h in a no-load condition. In a study conducted on a 66 W (PV powered) refrigeration system in Saudi Arabia, it was stated that solar energy is sufficient to run this system [5]. El-Tom et al. [6] studied the suitability of a PV solar refrigerator for preserving vaccines in Sudan. Power from the PV solar energy generator was provided to run the compressor (24 V DC motor) of the fridge. They noticed that the energy obtained from the solar generator was not enough to fully charge the battery so that it could operate the refrigerator overnight at full load. Gupta et al. [7] found that a refrigerator of 25 mm insulation thickness would run at optimal conditions when powered by a solar energy generator consists of 320W PV panel and 50 Ah battery capacity. However, 200W PV panel was sufficient if insulation thickness was 50 mm. Kattakayam and Srinivasan [8] found that the refrigerator operated by the PV energy source can work uninterrupted if it was backed up by gasoline/kerosene or diesel generator set and this is a suitable alternative for the storage of vaccines and life-saving drugs. In another experiment, Kattakayam and Srinivasan [9] drove a home fridge with non-sinusoidal AC input. This input was obtained from a PV-battery-inverter source. In this experiment, no degradation had been found in the thermal capacity of the fridge although they suggested that the vaccine should not be stored near the open end of the fridge door. Battery capacity plays an important role in the PV refrigeration system. To fetch maximum output from a battery, an appropriate system sizing is needed. Additionally, state-of-charge of a battery must occur in between 0.5-0.8 [10]. Modi et al. [11] redesigned a 165 litres domestic refrigerator to a PV powered refrigerator. After this modification, the COP of the system varied from morning to evening. The maximum COP, i.e. 2.102 was noticed at 7 am. The minimum requirements for this system to work properly was 140 W PV capacity and two 12 V/135 Ah battery bank. Nagaraju et al. [12] developed a PV-powered cold storage plant to store 10 tons of frozen fish at -15 °C. This system worked at its full potential in one full year. Later on, performance degradation was noticed owing to deterioration in PV panels. Xi et al. [13] investigated the performance of a PV refrigerator of 24V. It was running steadily with a rate of 48.8% in no-load condition. In this operation, an average of 28.8W power was consumed. This system can be operated continuously for 25 days in sunny conditions, six days in cloudy state and five days in overcast or rainy condition. Rathore and Panwar [14] investigated the PV refrigeration system and obtained minimum -3.36 °C temperature at no load condition

and 2.34 °C temperature at fully loaded conditions. In [Table 1], a compilation of different configurations of PV-driven refrigeration systems employed for various applications is provided.

Table 1: Various configurations of PV-driven refrigeration systems and respective parameters

S. No.	Configurations	Parameters	DC or AC	Energy Storage	Applications	Ref.
1.	PV+DC motor	PV Modules: 20 (120 Wp each)	DC motor: 650W/24V	Latent heat of frozen water	150 L milk storage tank	[1]
2.	PV+DC motor	PV module: 240 Wp Refrigerant: R134a	DC-powered compressor unit: 80 W	Latent heat of frozen water	250 L Standalone DC solar refrigerator	[4]
3.	PV+Battery+DC motor	PV module: 100 W Refrigerant: R134a DC power rating: 66W	Lead acid batteries: 12 V/50 Ah	Batteries charging	80 L Domestic fridge	[5]
4.	PV+Battery+DC motor	PV Modules: 6 (40 W each) Refrigerant: R12	Batteries: 2 (12 V/105Ah each) DC motor compressor: 24 V	Batteries charging	180 L Refrigerator	[6]
5.	PV+Battery+DC motor	PV Modules: 2 (70 Wp each) Refrigerant: R134a	Battery: 2 (12V each) DC compressor: 66W	Batteries charging	90 L Refrigerator	[13]
6.	PV+Battery+DC motor	PV Modules: 134 (30 Wp each) Average efficiency per panel: 9% Refrigeration load: 21 kWh	Lead acid battery: 15 (6.3V/180Ah each) DC-powered compressor unit: 3 kW/90V	Batteries charging	Cold Chamber Volume: 21 m ³	[12]
7.	PV+Battery+Inverter	PV Modules (series parallel combination): 8 (35 Wp each) AC Refrigerator: 110W	Inverter: 1.5 kVA Lead acid battery: 2 (12V/135Ah each)	Batteries charging	50 L Refrigerator	[7]
8.	PV+Battery+Inverter	PV Modules (series parallel combination): 4 (35 Wp each) Refrigerant: R-134a AC Refrigerator: 110 W	Inverter-transformer system Lead acid battery: 2 (12V/135Ah each)	Batteries charging	165 L Domestic Refrigerator	[11]
9.	PV+Battery+Invertor+generator set	PV Modules: 8 (35 Wp each) AC Refrigerator: 120-140 W	Invertor: 1.2 kVA Lead acid battery: 4 (6V/180Ah each) Back-up generator set: 1.0 kVA	Batteries charging	165 L Domestic Refrigerator	[8]

MODELLING AND SIMULATION STUDIES ON PV REFRIGERATION SYSTEMS

Sukamongkol et al. [15] developed a simulation model to predict the performance of a PV system at specific loading conditions for a particular location. This system was validated by a similar experimental system. Results obtained from both the methods were almost in good agreement with each other. Cherif and Dhouib [16] had demonstrated the performance of PV refrigeration plant with latent storage through dynamic behavior and simulation responses. They found that PV systems showed good performance, reliability and autonomy if climate conditions were favourable. In these conditions, the system is almost invulnerable to situations like door-opening and load disturbances. However, the performance and efficiency of this system are relatively low with solar radiation disturbances. Del Pero et al. [4] proposed an energy model to analyze the energy performance of the PV powered refrigeration kit. Refrigerator temperature and water container temperature were accessed using the model. The model was validated by testing its results on a developed prototype, and it was noticed that the deviation was only 0.4 °C from the predicted values.

ECONOMICAL ASPECT OF PV REFRIGERATION SYSTEM

In a solar trailer, a roof-mounted PV array charges batteries and the battery power employed to run an electric fridge via inverters. For this type of application, a PV driven cooling system is a suitable alternative because its maintenance and operational cost are extremely low. A PV cooling system fitted aircraft catering uplift vehicle is also economical for a longer operational period than the conventional one. The same fact is also true for household milk delivery van. In the previously described applications, the use of a PV driven cooling system is not only cheap but also a long-lasting non-maintenance system [17]. El-Shaarawi et al. [5] found that a 66 W refrigerator powered by a PV mono-crystalline module with a 100 Ah battery bank is relatively costlier, and the payback period is around 25 years. Modi et al. [11] performed the economic feasibility of the redesigned refrigerator in the RETScreen simulations and found that the

system is not economically viable without external aid. With the rise in refrigeration capacity and the increment in solar radiation, the specific price of refrigeration power decreases [18].

PHOTOVOLTAIC/THERMAL (PVT) REFRIGERATION SYSTEMS

It is well known that PV cells convert solar radiation into electrical energy. However, the conversion efficiency of these PV cells is 10-20% only. Some complex multi-junction PV cells also have the conversion capacity of up to 39%, but still, this energy efficiency is not enough to run modern equipment. In addition, more than half of the solar radiation, stored with considerable effort is wasted in the form of heat. The efficiency of this system can be enhanced if, by any means, this waste heat is collected and utilized again. This idea can be embodied by placing a heat exchanger behind the PV cells. This system is known as photovoltaic/thermal (PV/T) collectors. The heat rejected by PV cells is used by the heat exchanger as input, resulted in minimum wastage of energy. Mittelman et al. [19] introduced a concentrating photovoltaic/thermal (CPVT) system to produce electrical as well as high-grade thermal energy simultaneously at high temperatures. The highest driving potential of the cooling machine was obtained at an operating temperature of 120°C. However, electricity production was lower. At 80°C, the electrical efficiency of CPVT was optimum. Xu et al. [20] proposed a new low CPVT system with constant volume refrigeration. The reported thermal and electrical efficiencies of the system were 39.4% and 14.1% respectively at a temperature of 40°C. Therefore the overall efficiency obtained from the experiment was 53.5%, which was lower than the simulated values (58.6%). The conversion efficiencies are considerable, and no external heating was needed for outlet flow. Renno [21] optimized the parameters of CPVT system to make it most conducive for the domestic application. They simulated the CPVT process using MATLAB and achieved the best possible parameters for extracting maximum output. To meet the energy demands of a home using CPVT process, two modules of 90 cells with 81 mm² area and concentrating mirrors of high concentration factor is required. At 90°C fluid outlet temperature, the CPVT system can be employed with an absorption heat pump. Tiwari et al. [22] did numerical calculations of fully covered semitransparent photovoltaic thermal-compound parabolic concentrator (PVT-CPC) and photovoltaic thermal-flat plate collector (PVT-FPC) in MATLAB to check the feasibility of the systems for vapor absorption refrigeration system (VARS). They found that both the collectors are self-sustained for VARS.

CONCLUSIONS

In this article, a detailed review of the development of solar-powered refrigeration system has been presented. Various approaches had been utilized to feed solar energy to the refrigeration system. In some cases, the PV current was supplied directly into the DC motor while in other cases the DC was converted to AC using an inverter, and after that, the compressor was operated using it. Alternative energy sources were also employed with PV energy in some studies to run the refrigeration system at its maximum efficiency. In many situations, it was affirmed that the energy obtained from the PV system is enough to run a household refrigerator. Nonetheless, the discrepancies of the solar-powered refrigeration system were also reported in some studies. The initial cost of establishing a PV powered refrigeration system was relatively high, which raises questions about its achievability. In the current scenario, the government aid or the availability of subsidized PV panels and other equipment can only provide this pollution-free technology to the public. Although this refrigeration technique has the potential, low conversion capacity of PV panels, rudimentary battery technology and the high cost of components are slowing down the progress of this green initiative. Upon the full development of this technique, not only domestic essentials and life-saving items can be preserved, but our environment will also be prevented from being polluted. The expansion of PV powered refrigeration technique is inherently dependent on the peculiar development of technologies such as PV panels and energy storage or holding devices. The development of high capacity portable energy storage devices and PV panels with more conversion efficiency can play an important role in popularizing this system.

CONFLICT OF INTEREST

None

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None

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ARTICLE

BREAST CANCER AND PHYTOCHEMICALS: THE CURRENT PERSPECTIVE

Nilanjan Das^{1*}, Nikita Nagpal², Shailee Singh Bankura², Kapila Kumar²¹Accendere, CL Educate Ltd., New Delhi, INDIA²Department of Biotechnology, Manav Rachna International Institute of Research and Studies, Faridabad, INDIA

ABSTRACT

Breast cancer affects one in eight women during their lives with higher mortality rate. The risk factors are age, older women possess higher risk, genes - there are two genes, BRCA1 and 2 (Breast Cancer Gene 1 and 2) that greatly increase the risk; women with family history of breast or ovarian cancer, personal factors - beginning periods before age 12 or going through menopause after age 55, overweight, using hormone replacement therapy, taking birth control pills, drinking alcohol, not having children or having children after age 35 or having dense breasts. Phytochemicals are compound that are produced by plants and they protect the cells from damage that could lead to cancer. The anticancer efficacy of phytochemicals such as flavonoids, flavanols, catechins, epicatechins, anthocyanins, anthocyanidins, isoflavones and polyphenols have been discussed in this article in regard to breast cancer especially focusing on quercetin, green tea phytochemicals and soy bioactives. Reported studies indicated that consumption of phytochemical rich foods in early part of life decreases the cancer risk. Phytochemicals mostly exhibit anticancer activity against the breast cancer by arresting cell growth and inducing apoptosis. This article emphasizes how phytochemicals exert their impact in prevention and therapy of breast cancer.

INTRODUCTION

Breast cancer is one of the leading cancers that cause death of a huge population worldwide [1]. The common type of breast cancer is ductal carcinoma, that begins in the lining of the milk ducts and lobular carcinoma, which begins in the lobules of breast. Breast cancer occurs in both women and men, although male breast cancer is rare. Estimated new cases and death from breast cancer in the U.S. in 2014 are new cases in female is 232,670 and in male is 2360 whereas the number of death in cases of female is 40000 and in case of male is 430 [2].

For the past two decades, the major cause of breast cancer in women is due to the hormone therapy after menopause. In recent years, incidence rate is slightly low in white women whereas the rate increases slightly in African American women. Breast cancer in female is higher in developing countries than in developed countries. Breast cancer tumours show expression of HER2 which is directly linked to deregulate the activation of intracellular mitogenic pathway. This results in aggressive tumor behaviour and resistance to chemotherapy. Several studies have demonstrated that polyphenolics from pomegranate, green tea, and cranberry are the potent inhibitors of cancer cell proliferation and induces apoptosis [3].

Consumption of fruits and vegetables has been consistently associated with a reduced risk of human cancers. Flavonoids are a group of potentially chemo protective compounds widely distributed in vegetables, fruits and beverages and have structures that consist of phenolic benzene rings linked to a heterocyclic pyre or pyrone. Flavonoids of 6 principal subgroups - anthocyanidins, catechins, flavanols, flavones, flavanones, and isoflavones, are relatively common in human diets. Flavonols (e.g., kaempferol, quercetin, and myricetin) are the abundant flavonoids in plant foods and are mainly present in apples, onions, leafy vegetables, broccoli, and berries. Flavones (e.g., apigenin and luteolin) and anthocyanidins are present in relatively small quantities in grains, leafy vegetables, and herbs. Catechins (e.g., catechin and epicatechin) are abundant in tea, grapes, apples, chocolate, and red wine. Flavanones (e.g., naringenin and hesperetin) are predominantly contained in citrus fruits and their juices. Isoflavones (e.g., daidzein and genistein) are mainly found in soybeans and soy-based products [4]. Flavonoids have many biological effects that may play a role in cancer prevention, including antimutagenic free radical scavenging, and anti-proliferative properties, regulation of cell cycle and cell signaling, and inhibition of angiogenesis.

Phytochemicals are compounds that are produced by plants and are found in fruits, vegetables, beans, grains, and other some plants. Some of the phytochemicals are believed to protect cells from damage that could lead to cancer. It is deduced that cancer risk can be reduced by as much as 40% by eating more fruits, vegetables, and plant foods that have certain phytochemicals in them. Some phytochemicals help to stop the formation of potential cancer-causing substances (carcinogens), helps stop carcinogens from attacking the cells, help cells stop and wipe out any cancer-like changes. In this article, an effort has been made to highlight the anticancer efficacies of phytochemicals mainly quercetin present in different fruits and vegetables, green tea phytochemicals and soy bioactives in amelioration of breast cancer.

KEY WORDS

Breast cancer,
quercetin, green tea,
soy phytochemicals,
anticancer.

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*Corresponding Author

Email:
nilanjan.das@accendere.co.in
Tel.: +91-8220473185

BIOEFFICACY OF PHYTOCHEMICALS AGAINST BREAST CANCER

Phytochemicals are non-nutritive plant chemicals that have disease prevention properties. The activity of phytochemicals against breast cancer has been studied in different experiments. The phytochemicals that show potential is quercetin, present in cranberry and tea-polyphenol epigallocatechin. The major anthocyanidin are galctosides and arabinosides of cyaniding and peonictin. It is found that anthocyanidin inhibits the oxidative process that is linked with the tumour growth. The proanthocyanidin contains two linkages, the $4\beta\rightarrow B$ which is a B-linkage that is common and others between $4\beta\rightarrow 8$ and $2\beta\rightarrow 0\rightarrow 7$ [5] which is an A-linkage that inhibits the tumour growth and has anti-proliferative effect in the selected cell line. The peel of cranberry fruit contains ursolic acid in a low concentration that induces apoptosis at high concentration and the inhibition is more in micromolar concentration. Cox 2 promotes the growth of cancer which is been inhibited by anythocyanidin.

Quercetin

Flavonoids, one of the remarkable phytochemicals remove the carcinogen by increasing the transcription of detoxification of enzymes. The flavonoids in different fruits and vegetables especially quercetin reduce the risk of different cancer [6]. Breast cancer tumours show overexpression of human epidermal growth factor receptor 2 [HER 2] which is directly linked to the deregulation of intracellular mitogenic pathway that results in aggressive tumour behaviour and resistance to chemotherapy. Quercetin is a flavonoid present in most of the fruits and vegetables. Lapatinib is an oral molecule that inhibits the growth of EGFR and HER2. When the activity of quercetin is studied on a two cancer cell line the one that is resistant to lapatinib (SK-BR-3-Lap R) and the other sensitive to lapatinib (SK-BR-3), it is found that quercetin suppressed the growth of both the cell line and the colony formation of lapatinib sensitive cell [SK-BR-3], but not the resistant cell [SK-BR-3-Lap R]. The inhibitory effect of phosphorylation on Akt and ERKs on the SK-BR-3 cell line was low when treated with quercetin and it had a strong inhibitory effect on the cell line treated with lapatinib. The accumulation of cell in G2/M phase and the reduction of G1 phase in SK-BR-3-Lap R and SK-BR-3 had a significant result on quercetin but when treated with lapatinib the cell accumulated in G1 phase only as found in SK-BR-3 cell line [7]. Apoptosis is induced on both cell lines by quercetin whereas lapatinib has no impact on the resistant cell. The volume of tumour in the breast cancer can be reduced by pomegranate extract (Pg), since it has cytotoxic and anti-inflammatory properties. The cancer cell line contains a specificity protein (Sp) transcription factors (Sp1, Sp3, Sp4) where Sp1 is involved in the regulation of NF- κ B. The Sp transcription factors mediate the growth of cell. The up regulation of genes, overexpression of Sp causes the cell to survive. The cytotoxic activities of Pg is studied in cancer cell line [BT474 and MDA-MB-231] and on non-cancer cell line (MCF-10F and MCF-12A). It has been found that the Sp is increased in the cancer cell line (BT474 and MDA-MB-231) by Micro-RNA-27A. When the cancer cell line becomes transfected with an antagomir of Micro-RNA-27a, it increases the zinc finger mRNA [ZBTB-10-Mrna] expression [8]. As a result, it suppresses the Sp and Sp dependent m-RNA in the cancer cell line. When the cancer cell line (BT474) is treated with Pg, it decreases the luciferase activity, which is been transfected with pNF- κ B-Luc and mi-RNA-27a activity is decreased by the antagomir that suppress the tumour cells [8]. Pg also increases the expression of SHIP [which is a 14kDa protein and it is a regulator of p13K] by the down regulation of mi-RNA-155, which is regulated by binding to the 3'UTR region of SHIP-1. The cell transfected with anti-miRNA-155 decreases the activity of NF- κ B in concentration dependent manner. Pg also decreases the mi-RNA-155 level that plays an important role in anti-inflammatory and cytotoxic efficiency. The hydroxyl radical that damage biomolecules and hypochlorous acid are harmful free radical. DPPH is also one such thing. PRME has a great scavenging activity on these free radicals. It also has a scavenging activity on nitrous oxide and peroxy nitrite anion. When, lung and breast carcinoma cell line and non-malignant cell lines were pre-treated with PRME and it showed anticancer activity against breast carcinoma but not against lung. PRME arrests the G2/M phase and S phase of breast cancer both in dose dependent and time-dependent manner and it increases the apoptosis. PRME inhibited almost all cell cycle protein, but cdk1 and cyclin A1 was not inhibited, which suggest that there is a transition from G2-M phase and S-G2 phase. When DNA is damaged, p53 which is a tumor suppressor is activated and it arrests the cell cycle and induce apoptosis. The initiation of caspase cascade is by two pathway. Once caspase 8 is activated, it releases cytochrome c from mitochondria which activates caspase 9 and induces apoptosis [9]. Similarly Bcl2/Bax protein ratio is also important apoptosis. When the breast carcinoma cells were treated with PRME, the ratio of Bcl2/Bax increases in a time dependent manner and induces apoptosis.

The human breast cancer resistance protein BCRP / ABCG2 which is a member of G subfamily of the large ATP-binding cassette (ABC) transporter family. This is known as efflux pump. BCRP is a half transporter with only six transmembrane helices (TMs) [10]. Glucuronidation is a significant metabolic pathway that facilitates efficient elimination and detoxification of numerous endo and xenobiotics. Targeting this feature, works are going on towards improving the efficacy of synthetic drugs and plant based bioactives for treating breast cancer.

Green tea polyphenols

It is evident from several studies that there is convincing risk reduction effects of green tea against mammary tumors. Overall data derived from case-control studies also show a dose-dependent, statistically

significant association between green tea intake and breast cancer risk reduction [3]. Moreover, differences in the green tea-breast cancer association by menopausal status (a beneficial effect mainly in premenopausal women) has been suggested in some studies though some studies showed no differences in results by menopausal status [11-14]. Regular intake of green tea might be a relevant factor for the lower incidence of breast cancer in Asian populations having multifarious beneficial properties; and there are supportive evidence of its protective effects in some epidemiological studies [15-17] while black tea intake, in contrast, appears to be unrelated to breast cancer risk in Asian and western populations [17]. Green tea is rich in tea catechins, namely epigallocatechin gallate (EGCG), epigallocatechin (EGC), epicatechin (EC), and epicatechin gallate (ECG), which possess several cancer chemo preventive characteristics including anti-oxidation, anti-inflammatory, anti-proliferative, and anti-angiogenic [18]. Few of the epidemiologic studies have investigated the relationship between green tea and breast cancer risk by hormone receptor status although in vitro studies show cytotoxic effects of EGCG toward breast cancer cells regardless of estrogen receptor status [19].

The bioavailability of tea polyphenols in human might also possess some influence in their efficacy against breast cancer [3]. Variations in genes involved in the metabolism of tea polyphenols may also amend the green tea-breast cancer association [3]. One of the most imperative conjugation reaction of the tea catechin is O-methylation by the catechol-O-methyltransferase (COMT) [20, 21]. Genetic polymorphisms of methylenetetrahydrofolate reductase (MTHFR) and thymidylate synthase (TYMS) genes in the folate pathway and angiotensin converting enzyme (ACE) in the angiotensin-II pathway have been found to influence the green tea-breast cancer association in respective studies [22, 23].

The risk of breast cancer is also associated with the concentration of circulating estrogens and androgens. The cross-sectional studies revealed that green tea intake lowers the circulating estrogens in pre and post-menopausal stage [24, 25]. The green tea intake did not differ the concentration of the estrone, estradiol and sex hormone binding globulin (SHBG) whereas testosterone concentration differed significantly when compared to non-green tea drinkers [24, 25]. IGF-1 is a peptide that stimulates mitosis and inhibits apoptosis. IGF-1 binds to a binding protein known as IGFB-3. They may influence the risk of breast cancer development. Green tea infusion influence it and inhibits the growth of breast cancer [26-28]. Adiponectin is a hormone secreted in adipocyte that is been up-regulated by catechin expressions. But it did not decrease the level of expression of adiponectin. Studies say that adiponectin level increases by the daily uptake of green tea among the Asian women [29, 30].

Green tea or EGCG did not have any effect on post-initiation stage. But oral admiration of polyphenon E in the drinking water can delay the tumour growth than the normal water [31]. The dosage of green tea also play an important role. Low dose delays the cancer. Green tea in combination with tamoxifen is more useful in suppressing the tumor. EGCG enhance the tamoxifen that induces apoptosis [32, 33]. Studies say that better understanding of EGCG only reduce the risk of cancer but also green tea before carcinogen can delay the breast cancer [32, 33]. SV40 mouse model proposed the chemopreventive effect of green tea [31] but the results are inconclusive and a better understanding of the mechanisms by which green tea reduces the risk of cancer is needed.

Catechins

Metastasis is the main cause of death in patients with breast cancer. The process of metastasis involves a series of cellular events in which cell motility of breast cancer cells takes place regulated by some factors referred as motility factors. During the process, autocrine motility factors (AMF) and Cry61 become activated upon stimulation by heregulin- β 1 (HRG) [34]. HRG activates the epidermal growth factor receptor-related protein B3 (ErbB3)/ErbB2 hetero-dimerization and its phosphorylation. (-)-Epigallocatechingallate (EGCG) and (-)-epigallocatechin (EGC) are major catechins in green tea. They are also found in other sources such as apples, plums, onion, hazelnuts, pecans etc. It has also been demonstrated that EGCG suppresses the growth of breast cancer cells including the MCF-7 human breast carcinoma cell line by inhibiting the overexpression of tumor-associated fatty acid synthase (FAS)[35]. It has been reported that while MCF-7 cells were incubated with either EGCG or EGC (each 30 μ M) for predetermined periods prior to treatment with HRG, EGCG blocked the ErbB2/ErbB3 heterodimerization incrementally with time [1]. Migration/invasion is an important step in the metastasis of breast cancer cells. Activation of ErbB3/ErbB2 heterodimers by HRG can contribute to metastasis by enhancing tumor cell invasion. HRG is capable of promoting the tumorigenicity and metastasis of MCF-7 cells in vivo [36]. EGC inhibited the migration/invasion of MCF-7 cells to the same extent as EGCG in the assay using Boyden chambers. However, EGC suppressed the phosphorylation of erbB2 and ErbB3 at a low cell confluence and did not activate Akt at either a low or high cell confluence [1]. EGCG inhibited the migration/invasion through down-regulation of ErbB2/ErbB3/P13K/Akt signaling, whereas EGC did so through pathways involving the disruption of the HRG-stimulated activation of ErbB2/ErbB3 but not Akt [1]. EGCG and EGC may have potential as anti-metastasis drugs against breast cancer to be used with/after anti-cancer drugs. Tumour-associated macrophages (TAM) play an important role in tumour microenvironment. Especially, M2 macrophages contribute to tumour progression depending upon the expression of NF- κ B. Tumour-derived exosomes can modulate tumor microenvironment by transferring miRNAs to immune cells. Exosomes are circular fragments of membrane released from the endosomes, and they are shed from the surface membranes of most cell types [37]. Macrophages populate the microenvironment of most tumors. EGCG has significant influence on tumor-derived exosomal miRNAs and TAM. Study using murine breast cancer cell line 4T1, used for ex vivo and in vivo experiments where tumor cells or TAM isolated from

murine tumour graft were incubated with exosome, derived from miR-16 inhibitor-transfected and/or EGCG-treated 4T1 cells [38]. It has been found that cytokines with high (IL-6 and TGF- β) and low (TNF- α) expression in M2 macrophages and chemokines for monocytes (CSF-1 and CCL-2) and molecules in NF- κ B pathway (IKK α and I κ -B) showed differential expression when evaluated by RT-qPCR or western blot [38]. Expression of chemokines for monocytes were low in tumour cells from EGCG-treated mice and cytokines of TAM was skewed from M2- into M1- like phagocyte by EGCG as evidenced by decreased IL-6 and TGF- β and increased TNF α . Ex-vivo incubation of isolated tumour cells with EGCG inhibited the CSF-1 and CCL-2 expression. It was observed that treatment with EGCG leads to up-regulation of miR-16, which might be transferred by exosome to TAMs and contributes to the suppression of NF- κ B, and inhibition of TAM infiltration and M2 polarization [38].

Soy bioactives

Soy isoflavanones can cause a decrease in the estrone (E1) and luteal phase estradiol (E2) in women without any significant variation in the pre and post- menopausal phase [39]. It is been found that Asian women who took soy isoflavones have high 2/16 α hydroxyl, a marker for lower cancer risk. It has also been reported that soy if taken regularly reduces the risk of acquiring cancer along with lower mammographic density, another marker of breast cancer (high density, high risk of cancer), similar to green tea which also reduces the mammographic density because of its anti-proliferative and anti-angiogenic capacity [39].

Higher production of NAF fluid also denotes high cancer risk. Regular consumption of soy causes a reduction of NAF fluid in post-menopausal women [39]. To know the activity of soy in breast cancer, isoflavones is injected directly into the breast tissue by breast reduction surgery, fine-needle biopsies. In the reduction surgery, the isoflavones concentration was low in hydrolysed breast tissue. Due to variation in gene, the effect of soy may differ. The time period of soy food consumption also influences its effect as anticancer agent. It has been found that consumption during the early part of life reduces the risk of cancer than the soy intake during the late life [40, 41]. The intestinal bacteria has the capacity to metabolise the isoflavones into equol, if the soy is taken in the early part of life it can produce equol that has a protective effect against the breast cancer in the later part of life.

Consumption of soy foods during childhood, in adolescence and during puberty may reduce mammary cancer risk in women [42]. Studies have also examined whether an exposure to genistein or soy protein isolate (SPI), either in utero or prepubertally, or a combination of both, affects later mammary tumorigenesis [42]. Moreover, in addition to genistin (the glucoside conjugate of genistein) and genistein (the aglycone), SPI contains daidzin (the glucoside conjugate) and daidzein (the aglycone), the other main IFs in soy. It has been found that daidzein has weaker oestrogenic properties than genistein. The third isoflavone of soy protein isolate is glycitin and its aglycone glycitein, but they are present only at low levels. Susceptibility to malignant transformation may increase due to exposure of Genistein/Soy protein isolate in utero, if the exposure continues to adulthood a reduction in risk may occur [42]. If an early life exposure to genistein, or other estrogenic compounds, alters breast cancer risk by targeting progenitor cells or epithelial stem, changes in apoptosis and cell proliferation are expected to be seen. Hereditary mutation in BRCA1 not only increase the risk of breast cancer but also risk for ovarian and prostate cancer. BRCA 1 interacts with RAD51 protein and, as a result, BRCA 1 is capable of acting as a gatekeeper in maintaining genomic integrity by preventing DNA damage and inducing DNA repair [43]. Dietary exposure to genistein can be protective in absence of functional BRCA1. Moreover, inactivating mutations or deletions of the PTEN gene are among the most common changes found in human cancers, especially breast cancer. The PTEN protein is a lipid phosphatase and has been suggested to act as a tumor suppressor [44]. Genistein promotes apoptosis in mammary epithelial cells by inducing PTEN [45]. The changes were accompanied by a decrease in mammary tumorigenesis. However, the focus is on changes in gene expression, especially involvement of genes like BRCA1 and PTEN. The effects on mammary gland morphology and signalling pathways induced by pubertal exposure to genistein mimic those induced by the oestrogenic environment of early first pregnancy [42].

Dietary exposure to soy foods is associated with lower mammary tumor risk and reduced body weight and adiposity in humans. Obesity is an independent risk factor for the development of hormone receptor-positive breast cancer in postmenopausal women. The level of pro-inflammatory cytokine interleukin-6 increases with body mass [46], and is considered to constitute a viable marker for poor prognosis in breast cancer patients. Soy protein isolate (SPI) and GEN-fortified casein (CAS) decreases mammary adipocytes cell size when they were exposed in limited amount [47]. Dietary SPI and GEN exposure reduce mammary adipocyte cell size which was accompanied by increased expression of tumor suppressors PTEN and E-cadherin in mammary tissue. MSF cells cultured in a differentiation medium with 40nM GEN showed reductions in mature triglyceride accumulation, adipocyte numbers, and PPAR- γ and fatty acid synthase transcript levels [47]. Adipose differentiation by GEN inhibition was accompanied by increased estrogen receptor β (Er β (Esr2)) gene expression and was modestly recapitulated by ER β -selective agonist 2,3-bis-(4-hydroxyphenyl)-propionitrile (DPN). Reduction of ER β expression by siRNA targeting increased Ppar γ transcripts levels and stromal fibroblast differentiation into mature adipocytes; the latter can be reversed by GEN but not DPN [47]. Therefore, it is evident that dietary factors may have mammary tumor-preventative effects independent of their effects on body size and adiposity by inhibiting local adipogenesis in the mammary fat pad.

Phytoestrogens

Phytoestrogens are a group of plant-derived substances that are structurally or functionally similar to estradiol [48, 49]. Phytoestrogens, especially soy, has been fuelled by epidemiologic studies that have suggested low incidence of breast cancer in countries with high soy intake. Isoflavones are the most common form of phytoestrogens and are found in all the plants variety, soy being the greatest dietary source [50]. The tumorigenicity has been found to be reduced in MCF-7 breast cancer cells with genistein treatment [50].

Polyphenols

Resveratrol, a polyphenol form of grapes and red wine has many health beneficial effects. They have neuro protective, anticancer, anti-inflammation, anti-ageing, anti-microbial and cardio properties. Resveratrol is mainly important for breast cancer since it has been shown to exert both estrogenic or ant estrogenic effects (depending upon the concentrations used) and binds to estrogen receptors ER α and ER β with comparable affinity [51]. Resveratrol has been shown to inhibit cell migration / invasion and metastasis in several types of cancer, especially breast cancer. Resveratrol at 50 μ M acts in an anti-estrogenic manner to reduce cell migration while, resveratrol at 5 μ M acts similar to estrogen which induces invasion, cell migration and formation of lamellipodia on ER α (-), ER β (+) MDA-MB-231 breast cancer cell line. Lamellipodia are actin structures found at the leading edge of migrating cells that are under Rac regulation [52]. Rac activity is decreased by 50 μ M resveratrol, whereas estrogen and 5 μ M resveratrol increases Rac activity in breast cancer cells. Higher concentrations of resveratrol inhibits Akt and MAPK activities and lower concentrations of resveratrol promotes proliferation in human cancer cells and induces Akt and MAPKs, among other tumorigenic signalling proteins. Therefore, the growth and metastasis of breast cancer are induced depending upon the dose of resveratrol.

CURRENT PERSPECTIVE

In recent times, several breast cancer studies going on targeting breast cancer genes, proliferation, apoptotic induction, inflammation, metastasis arrest etc. involving phytochemicals such as curcumin, oregano, apigenin, sulforaphane, lutein, sesamin, beta-sitosterol etc. in pre-clinical trials [53, 54]. A combination of synthetic and natural drugs or two or more natural drugs working in synergy targeting breast cancer is a likely futuristic approach.

CONCLUSION

From the studies it is been inferred that any flavonoids should be taken at early stage of life for better result, since the breast cancer is been suppressed by dose and time dependent manner. Among the different flavonoids studied quercetin plays a major role in cancer treatment. It has good inhibitory effect against cancerous growth and induces apoptosis. Since it has good anti-cancer properties it can be used as adjuvant or a drug to treat the cancer. Adjuvant is used to remove the secondary tumour growth. Most of the adjuvant used in the cancer treatment have their own side effect. But quercetin would not have much side effect as others since it is naturally obtained from the plants. Some amount of quercetin can used in the chemotherapy drug for better result. But studies should be conducted to prove it. It was also inferred that consumption of soy foods during childhood and adolescence in women reduces mammary cancer risk. Genistein/SPI exposure limited to the prepubertal period appears to reduce later mammary cancer risk but the effect is mostly lost if the exposure remains risk. It was also established that early first pregnancy (before 20 years of age) reduces breast cancer risk, while women undergoing first pregnancy after 35 years of age are at increased risk. Obesity also increases breast cancer in women. Consumption of grapes, pomegranate and cranberry also reduces the risk of breast cancer. Green tea phytochemicals especially EGCG also possess significant beneficial effect in breast cancer. However, further studies including clinical trials are needed to validate the potential of these phytochemicals as an alternative but effective measures in amelioration of breast cancer.

CONFLICT OF INTEREST

There is no conflict of interest among authors.

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