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Interdisciplinary

Highlights

Biological Activities of Stem Bark

Analysis of Squeezing Amplification

Alternative Preservation Technique

One-Mode Subharmonic Generation

Discovering Thoughts, Inventing Future

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Ohmic Heating is an Alternative Preservation Technique-A Review

By Shivmurti, S., Rinkita, P., Harshit, P. & Smit, P.

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Abstract- Ohmic heating offers an alternating to conventional heating because it simultaneously heats both phases by internal energy generated through electrical energy. In this process heating rate depends upon the electrical conductivity and field strength. By this method a product undergoes a minimum structural damage, retain its nutritional value. This technique gives excellent processed quality products in minimum operating time. Electrical conductivity of food products is linear with different temperature range. Energy during ohmic heating is dissipated directly into the foods. Ohmic heating can be utilized in different preprocessing and processing operations like blanching, evaporation, dehydration, fermentation, extraction, sterilization, pasteurization etc. Additionally research revealed that there is no protein denaturation at high temperature when heated with ohmic heating, also in the presence of starch, unusual conductivity behaviors found due to starch gelatinization.

Keywords: ohmic heating, electrical conductivity.

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OHMICHEATINGISANALTERNATIVEPRESERVATIONTECHNIQUEAREVIEW

Strictly as per the compliance and regulations of :

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Shivmurti, S. ᵃ, Rinkita, P. ᵒ, Harshit, P. ᵖ & Smit, P. ᵚ

Abstract- Ohmic heating offers an alternating to conventional heating because it simultaneously heats both phases by internal energy generated through electrical energy. In this process heating rate depends upon the electrical conductivity and field strength. By this method a product undergoes a minimum structural damage, retain its nutritional value. This technique gives excellent processed quality products in minimum operating time. Electrical conductivity of food products is linear with different temperature range. Energy during ohmic heating is dissipated directly into the foods. Ohmic heating can be utilized in different preprocessing and processing operations like blanching, evaporation, dehydration, fermentation, extraction, sterilization, pasteurization etc. Additionally research revealed that there is no protein denaturation at high temperature when heated with ohmic heating, also in the presence of starch, unusual conductivity behaviors found due to starch gelatinization.

Keywords: ohmic heating, electrical conductivity.

I. Introduction

The rate of transfer of heat is low to the cold point in conventional aseptic processing, long processing times required but destruction of nutritional and sensory attributes, productivity is less and high cost of energy (Mitchell, 1989; Smith et al., 1990). It is difficult to apply aseptic processing for high pH large particles viscous liquids. In conventional aseptic heating, it is not possible to sterilize particulate foods at temperatures much above 130°C without serious overheating of the liquid phase (Parrot, 1992). Ohmic heating has been seen as a promising development to solve problems encountered in aseptic processing of low acid liquids containing particulates. Several authors have demonstrated that in ohmic heating, centre of the particle heats faster other than the liquid (de Alwis et al., 1989; Sastry and Palaniappan, 1992). Ohmic heating offers an alternating because it simultaneously heats both phases by internal energy generation (Palaniappan and Sastry, 2002). The most favorable conditions where electrical conductivities of fluid and solid particle are equal mainly when do the processing of particulates foods (Wang and Sastry, 1993a). Heating rate depends upon the electrical conductivity and electric field strength and also directly proportional to that (Sastry and Palaniappan, 1992). By this method a product undergoes a minimum structural damage, retains its nutritional value and also gives excellent processed quality products in minimum operating time (Rahman, 1999). The critical property affecting energy generation is the electrical conductivity of the material (Palaniappan and Sastry, 1991).

Low acid foods with particulates can be continuous sterilized by ohmic heating.(Palaniappan and Sastry,2002). Residence Time Distribution (RTD) measurement is needed because of the difficulty in measurement of the particle internal temperature during continuous flow (Sastry and Cornelius, 2002). Some of the researcher had studied the RTD of food particle in holding tube (Dutta and Sastry, 1990a; Salengke and Sastry, 1995; Salengke and Sastry, 1996; Alhamdan and Sastry, 1997). To find out RTD of any particulate foods, ultrasonic method is widely used when processed through ohmic heating (Marcotte et al., 2000). Ohmic heating technique widely used to blanching of vegetables (Mizarahi et al., 1975), thawing of frozen foods (Naveh et al., 1983). It can also be used for evaporation, dehydration, fermentation and extraction (Butz et al., 2002). Microbial inactivation is also carried out by ohmic heating process. The electrical pretreatments can reduce the intensity of using additional thermal methods to inactivate the microbes (Cho et al., 1996).

II. Electrical Conductivity

Electrical conductivity is the main critical parameter for heating the food material by joule heating techniques (Palaniappan and Sastry, 1991). Several food materials electrical conductivity have been experimented by many scientist. Electrical conductivity of some liquid foods is measured at different temperature (Ruhlman et al., 2001). Electrical conductivity of different solid foods is also measured (Mitchell and de Alwis, 1989). Mostly food contains the some parts of salts and acids causes electric current pass through the food and generate heat inside it (Palaniappan and Sastry, 1991). With this result, increase the electrolytic content causing increase in the electrical conductivity. (Wang and Sastry, 1993a,b).This effect may be accomplished via the relatively slow soaking or marination process or the more rapid blanching process in salt solution. Diffusion of salt in pork and beef has been studied by many researchers (Wistreich et al., 1960; Del Valle and Nickerson, 1976a,b; Dussap and Gros,1980). Some researcher had

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determined salt diffusivity in vegetable tissues (Drusas and Vagenas, 1988; Wang and Sastry, 1993b). Electrical conductivity of water chestnut increased with temperature and salt concentration. Relationship with temperature and salt concentration is found to be $R^2 = 0.98$. Electrical conductivity also changes with the change in the voltage and increase in the temperature as shown in Figure 1. By increasing the temperature, ohmic heating seems to be more effective (Sastry and Palaniappan, 1992). Figure 2 explain the linear increase in electrical conductivity with temperature (Palaniappan and Sastry, 1991; Castro et al., 2003). Figure 3 also supports the same statement for lean pork, which states that at higher temperature (above 100°C) tenderloin is more conductive than loin and shoulder (Sanjay et al., 2007).

The heating rate of particle liquid mixture depends on conductivity of mixture and the volume of each phase (Sastry and Palaniappan, 1992b). The reason of this is, as particle content increases, the path of current through the fluid, forcing the total currents to flow through the particles. This will be caused in more energy generation within the particles and a greater particle heating rates. It is also concluded that the range of electrical conductivity of the food products should be in the range from 0.01 S/m to 10 S/m. Food products which is used should have pH more than 4.6 and solid particulates food have solid to liquid ratio 40:60 (Palaniappan and Sastry, 1991). Several researches have been done on electrical conductivity of fruits and concluded that electrical conductivity of pear (0.041 S/m) and apple (0.023 S/m) measured at 25°C (Mitchell and de Alwis, 1989). Electrical conductivity of fresh strawberry was measured at 25°C 0.05 S/m, and at 100°C 0.55 S/m (Castro and Sastry et al., 2003). It can be observed from Table 1 is that the conductivity of strawberry increased from 0.186 S/m at 25°C to about 0.982 S/m at 100°C . Electrical conductivity of different pork cuts observed that lean is highly conductive compare to fat (Shirsat et al., 2004). The electrical conductivity of the individual components of the chicken chowmein over the process sterilization temperature range was measured at 27°C (2.1 S/m) and 140°C (6.8 S/m) (Tulsiyan et al., 2007).

III. Starch Gelatinization

Conductivity of foods has been found affected by physical structures. Experiment was carried out on several foods, and result was reported that certain food component, such as fat or starch might cause unusual conductivity behaviors during ohmic heating (Halden et al., 1990). If food product containing starch then care should be taken during ohmic heating because it causes starch gelatinization. There is a slight change in the heating curves of potato (Halden et al., 1990). When applying this heating to particulate foods, conductivity

was found to decrease with solids content and the particle size because it decreases the mobility of the ions (Palaniappan and Sastry, 1991b). Study on starch gelatinization is very important because there are many processes like extrusion, aseptic processing, sterilization etc., which are related to starch gelatinization. This change in a potato slice during ohmic heating was observed. The data explained that the major changes in electrical conductivity of the heated potato occurred at 40–50 °C and 75–80 °C. It is concluded that the starch gelatinization must be explained at higher temperature. A method was developed to get the degree of starch gelatinization by ohmic heating (Wang and Sastry, 1997).

IV. Effects on Physiochemical Property of Foods

Food products like cloudberry jam and goat milk were tested. All the chemical analysis were performed to find the total and volatile solids, ash, titratable acidity, ascorbic acid, total sugars, total fatty acids, total phenolic compounds and anthocyanins content, shown in Table 2 (Pereira et al., 2006). During ohmic heating moisture content of food products are also changes. From Table 3 the results of chemical analysis indicate that ohmic heating and conventional heating technology gives products with similar chemical properties. This is important because it allows the producers to replace the methods without major changes in their final products. Ohmic heating was also applied to the tomato paste. Tomato was exposed to ohmic heating with the voltage range from 6–14 V/cm. All data were taken at the temperature range from 26 to 96°C. This study showed a linear increase in conductivity values with increasing temperature. The value of "P" is always less than 0.05, which shows that the voltage gradient was statistically significant on the heating time. The variation in the pH noticed in the range of 4.20 to 4.51 (Hosain et al., 2012). Figure 4 explains the change in electrical conductivity when tomato is exposed to different voltage gradient and found to be statistically insignificant (P > 0.05).

Figure 5 revealed that the increase in voltage, heating time to reach the specific temperature decreased and found statistically significant. The ohmic heating rates were 0.325, 0.647, 1.495 and 2.031°C/s at voltage gradients 6, 8, 10, 12 and 14 V/cm, respectively. Various other parameter of milk was tested and that was found that at 40°C electrical conductivity was increased and viscosity was decreased with increasing temperature. Pasteurized milk chemical composition and its pH were not influenced in electrical field (Assad et al., 2013).

The results showed in Figure 6 that the viscosity of milk decreased with increasing temperature and this because the increase in temperature leads to lower milk

fatty blocs responsible for the high viscosity of milk. The relationships between viscosity and temperature are first-order equations for all electrical fields. Milk density was reduced with increasing milk temperature as shown in Figure 7. This reduction is after the rising of milk temperature above 40^0C (Muhsin, 2012). The results also showed that the differences in the density between electrical fields were not significant at all temperatures.

V. Effect on Microbial Quality

The comparison of ohmic heating and conventional heating were carried out with respect to inactivation effect on viable aerobes and *Streptococus Thermophilus* 2646 in milk under same temperature exposure. The quality of milk in terms of degree of protein denaturation were also studied in both conventional and ohmic heating and found that microbial counts and calculated decimal reduction time (D value) resulting from ohmic heating was significantly lower than those resulting from conventional heating. It was also concluded that there was no difference in degree of protein denaturation during the two treatments. Ohmic heating had thermal and non thermal lethal effect on microorganism. (Huixian *et al.,* 2007).The initial counts of viable aerobes and the initial counts of *Streptococus Thermophilus* were almost the same. During treatments, when the set temperature achieved, the total microbial counts were reduced, which is greater in ohmic heating than those in conventional heating. Moreover, for both viable aerobes and *Streptococus Thermophilus*, microbial counts were significantly different ($P<0.05$) between the two treatments at each temperature (Kazuhiko *et al.,* 2007).

VI. Fouling Effect

Heating process of the food products like pasteurization, sterilization etc, is performed to inactivate or kill the microbes or protect the food products against any microbiological changes. But there is very fair possibility that the product may lower its quality. During heating process, heat transfer equipments undergo the effect of fouling. This fouling lowers heat transfer, efficiencies and production loss etc. Bansal, *et al.,* (2005) heated milk in ohmic heater and found that fouling was enhanced when the temperature of milk at the inlet was decreased. If the milk flow rate is increased by double then the fouling rate was observed to be minimal. The reason of the influence on overall fouling rate might be the extent of protein reactions, different deposition rates for denatured and aggregated proteins and fluid hydrodynamic forces. Skim milk fouling curve is shown in Figure 8. The effect of milk temperature at the inlet of the ohmic heater is shown in Figure 9. Low fouling has been noticed when a reduction in the inlet temperature and corresponding to the tank temperature (Bansal, *et al.,* 2005). During the

supply of high current and stainless steel material electrode is used, rapid drop in power was recorded whereas the best results were obtained using graphite electrodes. The effect of the flow rate is shown in Figure10.

VII. Conclusion

Innovations in food processing techniques can significantly contribute to meeting the needs of the future with respect to quality, quantity and sustainability. Ohmic heating is one of the emerging technologies with enormous applications in the sector of food processing. Some of the possible applications are blanching, evaporation, dehydration, fermentation, extraction, sterilization, pasteurization and heating of foods to serving temperature. Research based on modeling on heating need to be done for complex foods, which may leads to the development of final packaging to the products. Fouling was increased when the temperature of milk reduced at the inlet and also doubles the milk flow rate. The reason of the influence on overall fouling rate might be the extent of protein reactions, different deposition rates for denatured and aggregated proteins and fluid hydrodynamic forces.

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Table 1 : Electrical conductivity versus temperatures of different fruits (Sanjay Sarang, 2007)

Temperature (ºC)	Apple –Green	Apple –Red	Peach	Pear	Pineapple	Strawberry
25	0.067±0.020a	0.075±0.016a	0.170±0.018b	0.084±0.019a	0.037±0.014c	0.186±0.047b
40	0.144±0.024a	0.138±0.011a	0.307±0.022b	0.173±0.009c	0.141±0.034a	0.335±0.060b
60	0.251±0.042a	0.239±0.031a	0.541±0.043b	0.313±0.059c	0.245±0.052a	0.592±0.108b
80	0.352±0.049a	0.339±0.047a	0.738±0.064b	0.439±0.082c	0.348±0.067a	0.801±0.148b
100	0.425±0.054a	0.419±0.053	0.941±0.092b	0.541±0.098c	0.432±0.070a	0.982±0.176b
120	0.504±0.059a	0.499±0.052a	1.123±0.130b	0.607±0.080c	0.506±0.080a	1.143±0.178b
140	0.571±0.072a	0.577±0.050a	1.299±0.176b	0.642±0.088c	0.575±0.081a	1.276±0.180b

Table 2 : Results of chemical analysis performed in unprocessed, ohmically processed and conventionally processed goat milk (Pereira *et al*., 2006)

Tests performed	Conventional	Ohmic	Unprocessed
pH	6.59 ± 0.04	6.59 ± 0.05	6.61 ± 0.07
Total Acidity (% lactic acid)	0.134 ± 0.003	0.124 ± 0.004	0.132 ± 0.003
Total Solids (%)	14.7 ± 0.30	14.9±0.1	14.7±0.1
Ash (%)	1.3 ± 0.1	1.1 ± 0.1	1.0 ± 0.1
TFA (g 100 g-1 of milk fat)	88.2 ± 4.7	86.5 ± 7.0	89.5 ± 10.6

Table 3 : Results of chemical analysis performed in unprocessed, ohmically processed and conventionally processed cloudberry jams (Pereira *et al*., 2006)

Tests performed	Conventional	Ohmic	Unprocessed
pH	3.83±0.03	3.65±0.10	3.37±0.06
Total Acidity (g Citric acid 100 g^{-1} of product)	6.18±0.08	6.01±0.01	6.34±0.08

Total Solids (%)	39.5±0.3	40.0±0.6	39.5±0.6
Ash (%)	0.23±0.01	0.23±0.02	0.21±0.01
Anthocyanins (mg$_{C3G}$ 100g^{-1} $_{of\ product}$)	0.036±0.02	0.36±0.01	0.70±0.02
Total Phonlics (mg$_{GAG}$ 100g^{-1} $_{of\ product}$)	149.4±7.4	150.9±1.8	144.5±3.6
Ascorbic Acid (mg 100 g^{-1} $_{of\ product}$)	2.88±0.08	2.76±0.08	3.08±0.10
Total Sugars (g$_{sgf}$ 100g^{-1} $_{of\ product}$)	46.48±0.95	47.37±1.11	34±2.39
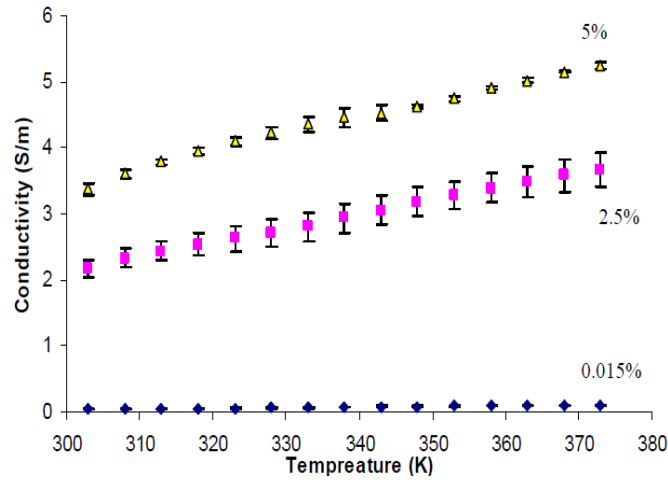
Figure 1 : Electrical conductivity variation with temperature, of water cheesenuts with .015%, 2.5%, 5% salt mass fractions
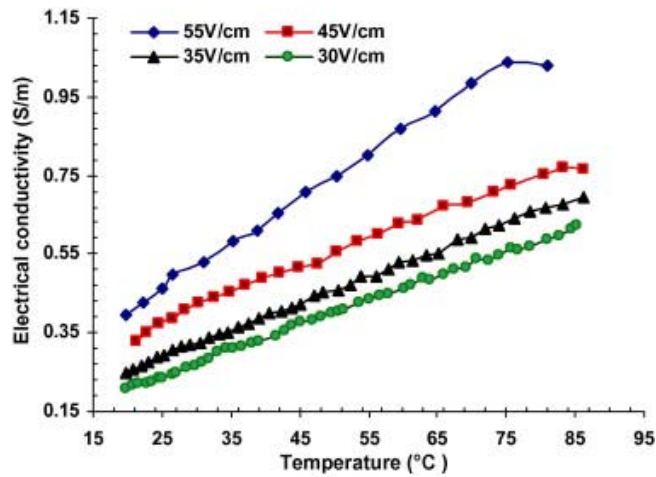
Figure 2 : Electrical conductivity changes with change in voltage
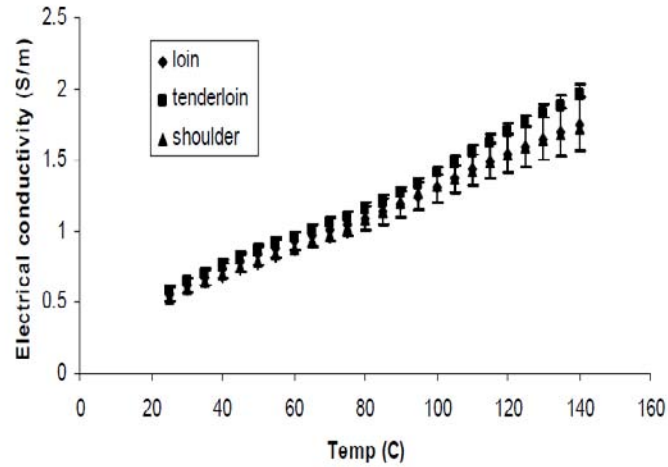
Figure 3 : Electrical conductivity of different pork cuts increases linearly with temperature
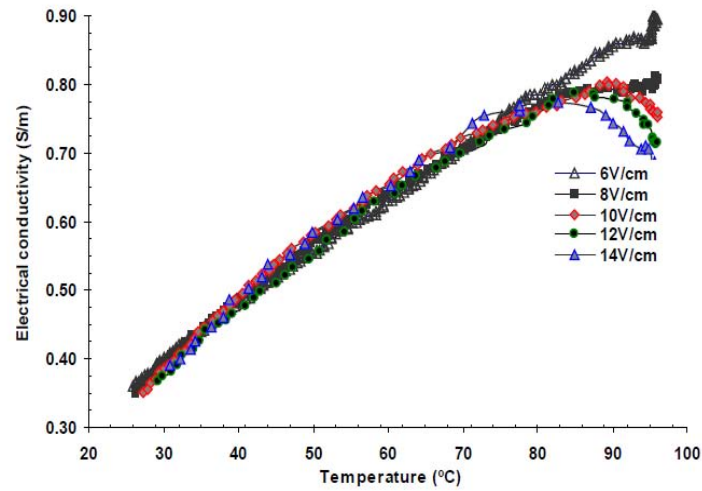
Figure 4 : Electrical conductivity of tomato versus temperature (Hosain Darvishi et. al ,2012)
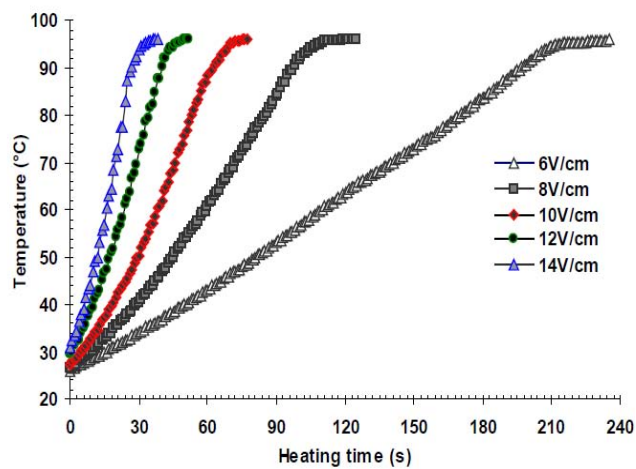
Figure 5 : Temperature and heating time curves of tomato samples at voltage gradient (Hosain Darvishi *et. al.,*2012)
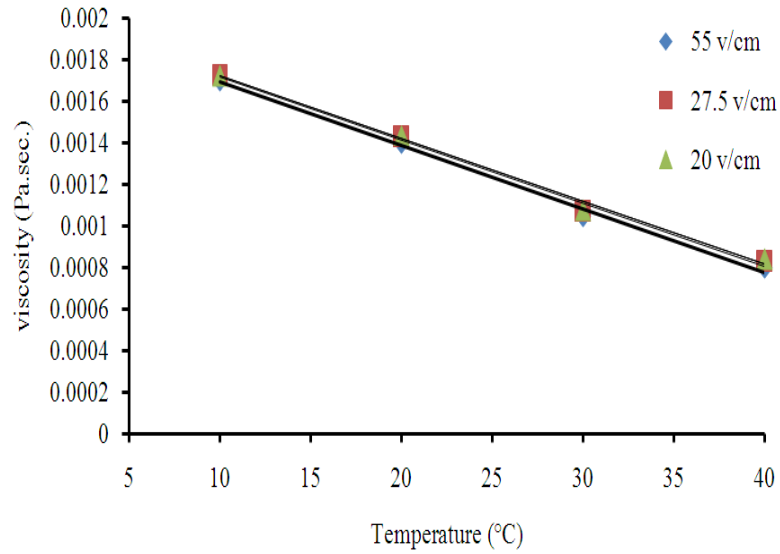
Figure 6 : Viscosity vs. temperature of milk at electrical field pasteurization (Assad Rehman Saeed Al –Hilphy, 2013)
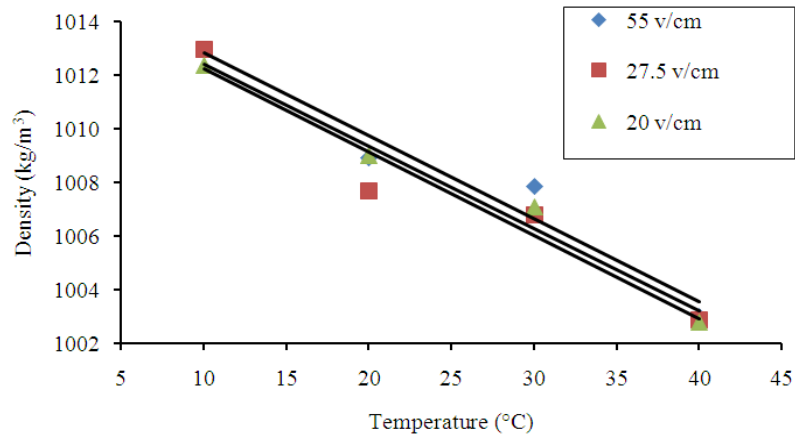
Figure 7 : Density vs. Temperature of pasteurized milk by electrical field (Assad Rehman Saeed Al –Hilphy, 2013)
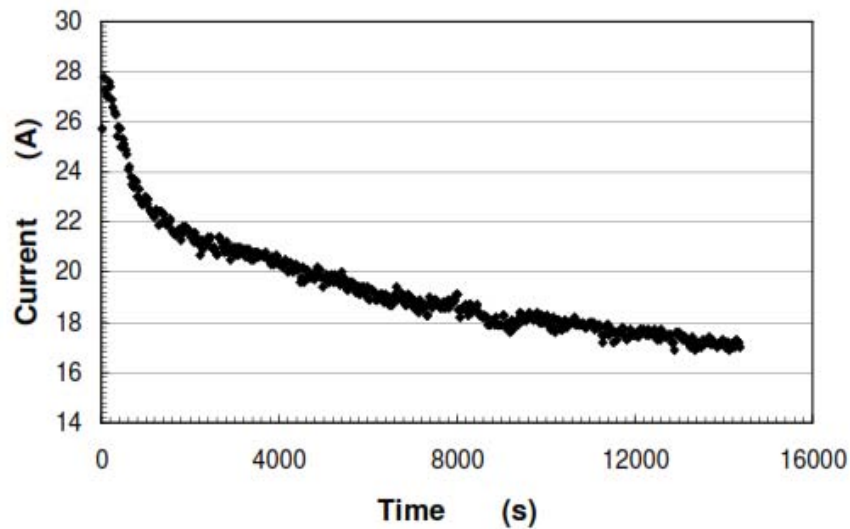
Figure 8 : Typical skim milk (5 wt %) fouling curve in the ohmic heater
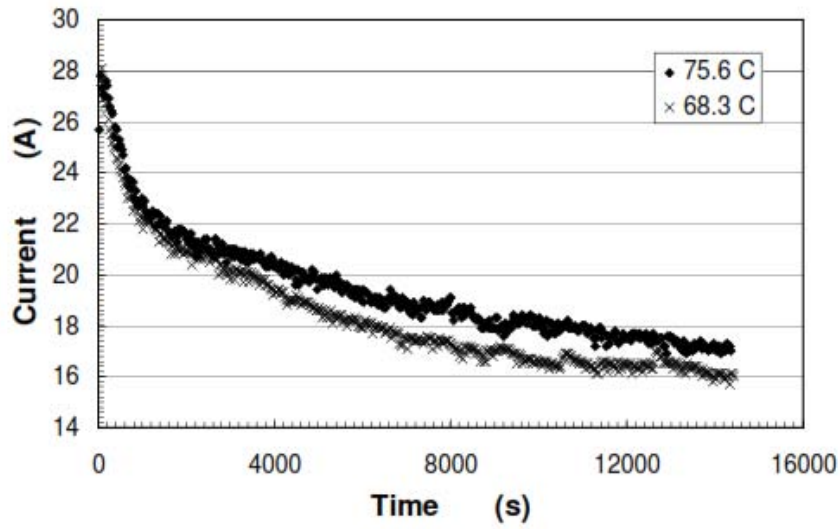
Figure 9 : Effect of milk inlet temperature on fouling
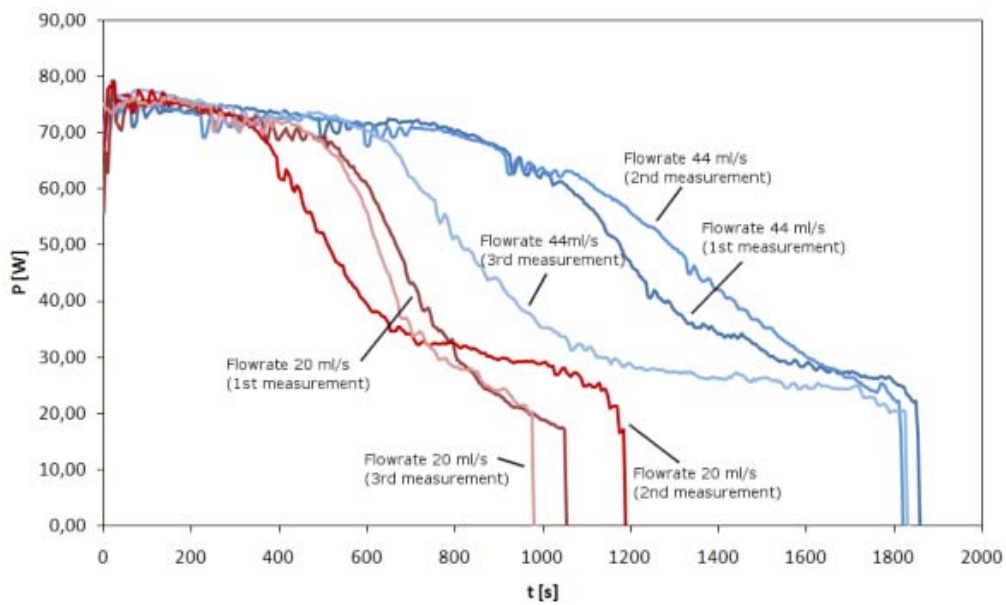
Figure 10 : Dependence of flow rate on milk fouling during direct ohmic heating

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A Refined Analysis of Squeezing Amplification in the One-Mode Subharmonic Generation

By Solomon Getahun

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Abstract- We have analyzed the statistical and squeezing properties of the signal mode applying the solution of c-number Langivin equations for the combination of the twin signal light beams. We have found that the mean photon number to be twofold of that of a twin signal light beam. And a large part of the mean photon number is confined in a relatively small frequency interval. In addition, we have shown that the local quadrature squeezing of the signal mode is in general greater than the global quadrature squeezing and approaches to the global quadrature squeezing as λ increases. Moreover, the one-mode subharmonic light beams have a maximum amplified squeezing of 75% below the vacuum state level and occurs in ± 0.01 frequency interval.

Keywords: signal mode, twin signal light beam, global, local, q function, photon statistics, quadrature squeezing.

GJSFR-E Classification : FOR Code : 020399

AREFINEDANALYSISOFSQUEEZINGAMPLIFICATIONINTHEONEMODESUBHARMONICGENERATION

Strictly as per the compliance and regulations of :

A Refined Analysis of Squeezing Amplification in the One-Mode Subharmonic Generation

Solomon Getahun

Abstract- We have analyzed the statistical and squeezing properties of the signal mode applying the solution of c-number Langivin equations for the combination of the twin signal light beams. We have found that the mean photon number to be twofold of that of a twin signal light beam. And a large part of the mean photon number is confined in a relatively small frequency interval. In addition, we have shown that the local quadrature squeezing of the signal mode is in general greater than the global quadrature squeezing and approaches to the global quadrature squeezing as λ increases . Moreover, the one mode subharmonic light beams have a maximum amplified squeezing of 75% below the vacuum state level and occurs in ± 0.01 frequency interval.

I. Introduction

One-mode subharmonic generation is one of the most interesting and widely studied quantum optical processes. In this process a pump photon of frequency 2ω is down converted into a pair of signal photons each of frequency ω. A theoretical analysis of the statistical and squeezing properties of the signal mode produced by one-mode subharmonic generation has been made by a number of authors [1-7]. Among other things, it has been predicted that the signal mode has a maximum squeezing of 50% below the vacuum-state level [4-7].

It is to be recalled that the Hamiltonian describing the process of subharmonic generation consists of the operators $\hat{a}^2$ and $\hat{a}^{\dagger 2}$. And the quantum analysis of the signal mode is usually carried out employing the operators $\hat{a}$ and $\hat{a}^\dagger$ with the commutation relation $[\hat{a}.\hat{a}^\dagger] = 1$. However, such analysis leads, among others, to one-half of the mean photon number of the signal mode [1-7]. This is surely the mean number of one set of the signal photons, consisting of one photon from each pair [6-7]. Since the other set of the signal photons is not included in such analysis, we seek to resolve this problem by applying the commutation relation $[\hat{a}.\hat{a}^\dagger] = 2$.

We therefore seek to analyze the statistical and squeezing properties of the signal mode applying the solution of c-number Langevin equations. We use this solution to calculate, in particular, the mean photon number and quadrature squeezing of the signal mode.

II. The Q function

We first obtain c-number Langevin equations, associated with the normal ordering, for the signal mode produced by one-mode subharmonic generation. The process of one-mode subharmonic generation is described by the Hamiltonian

$$\hat{H} = i\mu(\hat{b}^\dagger - \hat{b}) + \frac{i\lambda}{2}(\hat{b}^\dagger \hat{a}^2 - \hat{b}\hat{a}^{\dagger 2}), \tag{1}$$

where $\hat{a}(\hat{b})$ is the annihilation operator for the signal mode (pump mode), λ is the coupling constant, and μ is proportional to the amplitude of the coherent light driving the pump mode. Applying (1) and taking into account the interaction of the pump and signal modes with two independent vacuum reservoirs, the master equation for the cavity modes can be written as

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$$\frac{d\hat{\rho}}{dt} = \mu(\hat{b}^\dagger\hat{\rho} - \hat{\rho}\hat{b}^\dagger + \hat{\rho}\hat{b} - \hat{b}\hat{\rho}) + \frac{\lambda}{2}(\hat{\rho}\hat{b}\hat{a}^{\dagger 2} - \hat{b}\hat{a}^{\dagger 2}\hat{\rho} + \hat{b}^\dagger\hat{a}^2\hat{\rho} - \hat{\rho}\hat{b}^\dagger\hat{a}^2)$$
$$+ \frac{\kappa}{2}\left(2\hat{a}\hat{\rho}\hat{a}^\dagger - \hat{a}^\dagger\hat{a}\hat{\rho} - \hat{\rho}\hat{a}^\dagger\hat{a}\right) + \frac{\kappa}{2}\left(2\hat{b}\hat{\rho}\hat{b}^\dagger - \hat{b}^\dagger\hat{b}\hat{\rho} - \hat{\rho}\hat{b}^\dagger\hat{b}\right), \tag{2}$$

in which κ is the cavity damping constant for the signal mode as well as the pump mode. Now employing the relations

$$\frac{d}{dt}\langle\hat{A}\rangle = Tr(\frac{d\hat{\rho}}{dt}\hat{A}) \tag{3}$$

and

$$[\hat{a}, \hat{a}^\dagger] = 2, \tag{4}$$

along with (2), one readily obtains

$$\frac{d}{dt}\langle\hat{a}(t)\rangle = -\kappa\langle\hat{a}(t)\rangle - 2\lambda\langle\hat{a}^\dagger(t)\hat{b}(t)\rangle, \tag{5}$$

$$\frac{d}{dt}\langle\hat{a}(t)\hat{a}(t)\rangle = -2\kappa\langle\hat{a}^2(t)\rangle - 4\lambda\langle\hat{a}^\dagger(t)\hat{a}(t)\hat{b}(t)\rangle - 2\lambda\langle\hat{b}(t)\rangle, \tag{6}$$

$$\frac{d}{dt}\langle\hat{a}^\dagger(t)\hat{a}(t)\rangle = -2\kappa\langle\hat{a}^\dagger(t)\hat{a}(t)\rangle - 2\lambda\left(\langle\hat{a}^2(t)\hat{b}^\dagger(t)\rangle + \langle\hat{a}^{\dagger 2}(t)\hat{b}(t)\rangle\right). \tag{7}$$

We note that the c-number equations corresponding to Eqs. (5), (6), and (7) are

$$\frac{d}{dt}\langle\alpha(t)\rangle = -\kappa\langle\alpha(t)\rangle - 2\lambda\langle\alpha^*(t)\beta(t)\rangle, \tag{8}$$

$$\frac{d}{dt}\langle\alpha(t)\alpha(t)\rangle = -2\kappa\langle\alpha^2(t)\rangle - 4\lambda\langle\alpha^*(t)\alpha(t)\beta(t)\rangle - 2\lambda\langle\beta(t)\rangle, \tag{9}$$

$$\frac{d}{dt}\langle\alpha^*(t)\alpha(t)\rangle = -2\kappa\langle\alpha^*(t)\alpha(t)\rangle - 2\lambda\left(\langle\alpha^2(t)\beta^*(t)\rangle + \langle\alpha^{*2}(t)\beta(t)\rangle\right). \tag{10}$$

On the basis of Eq. (5), one can write

$$\frac{d}{dt}\alpha(t) = -\kappa\alpha(t) - 2\lambda\alpha^*(t)\beta(t) + f_\alpha(t), \tag{11}$$

where $f_\alpha(t)$ is a noise force whose properties remain to be determined. We note that Eq. (8) and the expectation value of Eq. (11) will have identical forms if

$$\langle f_\alpha(t)\rangle = 0. \tag{12}$$

Moreover, it can be readily verified using (11) that

$$\frac{d}{dt}\langle\alpha(t)\alpha(t)\rangle = -2\kappa\langle\alpha^2(t)\rangle - 4\lambda\langle\alpha^*(t)\alpha(t)\beta(t)\rangle + 2\langle\alpha(t)f_\alpha(t)\rangle. \tag{13}$$

Comparison of Eqs. (9) and (13) shows that

$$\langle\alpha(t)f_\alpha(t)\rangle = -\lambda\langle\beta(t)\rangle. \tag{14}$$

A formal solution of Eq. (11) can be written as

$$\alpha(t) = \alpha(0)e^{-\kappa t} + \int^t e^{-\kappa(t-t')}[f_\alpha(t') - 2\lambda\beta(t')\alpha^*(t')]dt'. \tag{15}$$

We then notice that

$$
\begin{aligned}
\langle \alpha(t) f(t) \rangle = & \langle \alpha(0) f_\alpha(t) \rangle e^{-\kappa t} + \int_0^t e^{-\kappa(t-t')} [\langle f_\alpha(t) f_\alpha(t') \rangle \\
& -2\lambda \langle \beta(t') \alpha^*(t') f_\alpha(t) \rangle] dt'.
\end{aligned}
\tag{16}
$$

On account of the assertion that a noise force at time t should not affect a cavity mode variable at earlier time, we have

$$
\langle \alpha(t) f_\alpha(t) \rangle = \int_0^t e^{-\kappa(t-t')} \langle f_\alpha(t) f_\alpha(t') \rangle dt',
\tag{17}
$$

so that in view of (14), there follows

$$
\int_0^t e^{-\kappa(t-t')} \langle f(t) f(t') \rangle dt' = -\lambda \langle \beta(t) \rangle.
\tag{18}
$$

Now on the basis of the relation

$$
\int_0^t e^{-a(t-t')} \langle f(t) g(t') \rangle dt' = D,
\tag{19}
$$

we assert that

$$
\langle f(t) g(t') \rangle = 2D\delta(t - t'),
\tag{20}
$$

where a is a constant and D is a constant or some function of time t. We then see that

$$
\langle f_\alpha(t) f_\alpha(t') \rangle = -2\lambda \langle \beta(t) \rangle \delta(t - t').
\tag{21}
$$

Furthermore, it can be verified applying (11) and its complex conjugate that

$$
\begin{aligned}
\frac{d}{dt} \langle \alpha^*(t)\alpha(t) \rangle = & -2\kappa \langle \alpha^*(t)\alpha(t) \rangle - 2\lambda \langle \beta(t)\alpha^{*2}(t) \rangle - 2\lambda \langle \beta^*(t)\alpha^2(t) \rangle \\
& + \langle \alpha^*(t) f_\alpha(t) \rangle + \langle \alpha(t) f_\alpha^*(t) \rangle.
\end{aligned}
\tag{22}
$$

On comparing this with (10), we observe that

$$
\langle \alpha^*(t) f_\alpha(t) \rangle + \langle \alpha(t) f_\alpha^*(t) \rangle = 0.
\tag{23}
$$

In addition, using (15) and its complex conjugate, we easily get

$$
\langle \alpha(t) f_\alpha^*(t) \rangle = \int_0^t e^{-\kappa(t-t')} \langle f_\alpha^*(t) f_\alpha(t') \rangle dt'
\tag{24}
$$

and

$$
\langle \alpha^*(t) f_\alpha(t) \rangle = \int_0^t e^{-\kappa(t-t')} \langle f_\alpha(t) f_\alpha^*(t') \rangle dt'.
\tag{25}
$$

Now taking into account (23), (24), (25), and assuming that

$$
\langle f_\alpha^*(t) f_\alpha(t') \rangle = \langle f_\alpha(t) f_\alpha^*(t') \rangle,
\tag{26}
$$

we arrive at

$$\int_0^t e^{-\kappa(t-t')}\langle f_\alpha^*(t)f_\alpha(t')\rangle dt' = \int_0^t e^{-\kappa(t-t')}\langle f_\alpha(t)f_\alpha^*(t')\rangle dt' = 0. \tag{27}$$

Therefore, on account of (19) and (20), we see that

$$\langle f_\alpha^*(t)f_\alpha(t')\rangle = \langle f_\alpha(t)f_\alpha^*(t')\rangle = 0. \tag{28}$$

It is worth mentioning that (12), (21), and (28) describe the correlation properties of the noise force $f_\alpha(t)$ which is associated with the normal ordering.

On the other hand, we wish to determine the correlation properties of the noise force associated with $\beta(t)$. To this end, employing the relation described by (3) and the commutation relation

$$[\hat{b}, \hat{b}^\dagger] = 1, \tag{29}$$

along with (2), one readily obtains

$$\frac{d}{dt}\langle\hat{b}(t)\rangle = -\frac{\kappa}{2}\langle\hat{b}(t)\rangle + \frac{\lambda}{2}\langle\hat{a}^2(t)\rangle + \mu, \tag{30}$$

$$\frac{d}{dt}\langle\hat{b}(t)\hat{b}(t)\rangle = -\kappa\langle\hat{b}^2(t)\rangle + 2\mu\langle\hat{b}(t)\rangle + \lambda\langle\hat{a}^2(t)\hat{b}(t)\rangle, \tag{31}$$

$$\frac{d}{dt}\langle\hat{b}^\dagger(t)\hat{b}(t)\rangle = -\kappa\langle\hat{b}^\dagger(t)\hat{b}(t)\rangle + \mu\Big(\langle\hat{b}^\dagger(t)\rangle + \langle\hat{b}(t)\rangle\Big)$$
$$+\frac{\lambda}{2}\Big(\langle\hat{a}^2(t)\hat{b}^\dagger(t)\rangle + \langle\hat{a}^{\dagger 2}(t)\hat{b}(t)\rangle\Big). \tag{32}$$

We see that the c-number equations corresponding to Eqs. (30), (31), and (32) are

$$\frac{d}{dt}\langle\beta(t)\rangle = -\frac{\kappa}{2}\langle\beta(t)\rangle + \frac{\lambda}{2}\langle\alpha^2(t)\rangle + \mu. \tag{33}$$

$$\frac{d}{dt}\langle\beta(t)\beta(t)\rangle = -\kappa\langle\beta^2(t)\rangle + 2\mu\langle\beta(t)\rangle + \lambda\langle\alpha^2(t)\beta(t)\rangle, \tag{34}$$

$$\frac{d}{dt}\langle\beta^*(t)\beta(t)\rangle = -\kappa\langle\beta^*(t)\beta(t)\rangle + \mu\Big(\langle\beta^*(t)\rangle + \langle\beta(t)\rangle\Big)$$
$$+\frac{\lambda}{2}\Big(\langle\alpha^2(t)\beta^*(t)\rangle + \langle\alpha^{*2}(t)\beta(t)\rangle\Big). \tag{35}$$

On the basis of Eq. (33), we can write

$$\frac{d}{dt}\beta(t) = -\frac{\kappa}{2}\beta(t) + \frac{\lambda}{2}\alpha^2(t) + \mu + f_\beta(t), \tag{36}$$

where $f_\beta(t)$ is a noise force the properties of which remain to be determined. We note that Eq. (33) and the expectation value of Eq. (36) will have identical forms if

$$\langle f_\beta(t)\rangle = 0. \tag{37}$$

Moreover, it can be readily verified using (36) that

$$\frac{d}{dt}\langle\beta(t)\beta(t)\rangle = -\kappa\langle\beta^2(t)\rangle + 2\mu\langle\beta(t)\rangle + \lambda\langle\alpha^2(t)\beta(t)\rangle + 2\langle\beta(t)f_\beta(t)\rangle. \tag{38}$$

Comparison of Eqs. (34) and (38) shows that

$$\langle\beta(t)f_\beta(t)\rangle = 0. \tag{39}$$

A formal solution of (36) can be written as

$$\beta(t) = \beta(0)e^{-\kappa t/2} + \int_0^t e^{-\kappa(t-t')/2}\left(f_\beta(t') + \frac{\lambda}{2}\alpha^2(t') + \mu\right)dt'. \tag{40}$$

We note that

$$\langle\beta(t)f_\beta(t)\rangle = \int_0^t e^{-\kappa(t-t')/2}\langle f_\beta(t')f_\beta(t)\rangle dt', \tag{41}$$

so that in view of (39) and (41) together with (19) and 20), there follows

$$\langle f_\beta(t')f_\beta(t)\rangle = 0. \tag{42}$$

Furthermore, employing Eqs. (36), we readily obtain

$$\begin{aligned}\frac{d}{dt}\langle\beta^*(t)\beta(t)\rangle &= -\kappa\langle\beta^*(t)\beta(t)\rangle + \frac{\lambda}{2}\left[\langle\alpha^{*2}(t)\beta(t)\rangle + \langle\alpha^2(t)\beta^*(t)\rangle\right] \\ &\quad + \mu\left(\langle\beta(t)\rangle + \langle\beta^*(t)\rangle\right) + \langle\beta^*(t)f_\beta(t)\rangle + \langle\beta(t)f_\beta^*(t)\rangle.\end{aligned} \tag{43}$$

On comparing this with Eq. (35), we have

$$\langle\beta^*(t)f_\beta(t)\rangle + \langle\beta(t)f_\beta^*(t)\rangle = 0. \tag{44}$$

In addition, with the aid of (40) and its complex conjugate, we easily get

$$\langle\beta(t)f_\beta^*(t)\rangle = \int_0^t e^{-\frac{\kappa(t-t')}{2}}\langle f_\beta^*(t)f_\beta(t')\rangle dt' \tag{45}$$

and

$$\langle\beta^*(t)f_\beta(t)\rangle = \int_0^t e^{-\frac{\kappa(t-t')}{2}}\langle f_\beta(t)f_\beta^*(t')\rangle dt'. \tag{46}$$

On account of Eq. (44), we have

$$\int_0^t e^{-\frac{\kappa(t-t')}{2}}\langle f_\beta^*(t)f_\beta(t')\rangle dt' + \int_0^t e^{-\frac{\kappa(t-t')}{2}}\langle f_\beta(t)f_\beta^*(t')\rangle dt' = 0. \tag{47}$$

And assuming that

$$\langle f_\beta^*(t)f_\beta(t')\rangle = \langle f_\beta(t)f_\beta^*(t')\rangle, \tag{48}$$

we arrive at

$$\int_0^t e^{-\frac{\kappa(t-t')}{2}}\langle f_\beta^*(t)f_\beta(t')\rangle dt' = \int_0^t e^{-\frac{\kappa(t-t')}{2}}\langle f_\beta(t)f_\beta^*(t')\rangle dt' = 0. \tag{49}$$

Thus with the aid of (19) and (20), we see that

$$\langle f_\beta^*(t')f_\beta(t)\rangle = \langle f_\beta(t')f_\beta^*(t)\rangle = 0. \tag{50}$$

Now on account of Eqs. (37), (42), and (50), we can drop the noise force in Eq. (36) and write

$$\frac{d}{dt}\beta(t) = -\frac{\kappa}{2}\beta(t) + \frac{\lambda}{2}\alpha^2(t) + \mu. \tag{51}$$

Applying the large time approximation scheme to this equation, we have

$$\beta(t) = \frac{2\mu}{\kappa} + \frac{\lambda}{\kappa}\alpha^2(t). \tag{52}$$

Then on substituting Eq. (52) into (11) and (21) and dropping terms second order in λ, we obtain

$$\frac{d}{dt}\alpha(t) = -\kappa\alpha(t) - 2\varepsilon\alpha^*(t) + f_\alpha(t) \tag{53}$$

and

$$\langle f_\alpha(t)f_\alpha(t')\rangle = \langle f_\alpha(t')f_\alpha(t)\rangle = -2\varepsilon\delta(t-t'), \tag{54}$$

where

$$\varepsilon = \frac{2\mu\lambda}{\kappa}. \tag{55}$$

In order to obtain the solution of Eq. (53), we introduce a new variable defined by

$$\alpha_\pm(t) = \frac{1}{2}\left[\alpha^*(t) \pm \alpha(t)\right]. \tag{56}$$

It can then be shown using (53) and its complex conjugate that

$$\frac{d\alpha_\pm(t)}{dt} = -\frac{1}{2}\xi_\pm\alpha_\pm(t) + \frac{1}{2}(f^*(t) \pm f(t)), \tag{57}$$

in which

$$\xi_\pm = \kappa \pm 2\varepsilon. \tag{58}$$

According to Eq. (57) together with (58), the equation of evolution of α_- does not have a well behaved solution for $\kappa < 2\varepsilon$. We then identify $\kappa = 2\varepsilon$ as the threshold condition. For $2\varepsilon < \kappa$, the solution of Eq. (57) can be written as

$$\alpha_\pm(t) = \alpha_\pm(0)e^{-\frac{1}{2}\xi_\pm t} + \frac{1}{2}\int_0^t e^{-\frac{1}{2}\xi_\pm(t-t')}[f^*(t') \pm f(t')]dt'. \tag{59}$$

Now with the aid of (56) and (59), one readily gets

$$\alpha(t) = F_+(t)\alpha(0) + F_-(t)\alpha^*(0) + E_+(t) - E_-(t), \tag{60}$$

in which

$$F_\pm(t) = \frac{1}{2}\left[e^{-\frac{1}{2}\xi_+ t} \pm e^{-\frac{1}{2}\xi_- t}\right] \tag{61}$$

and

$$E_\pm(t) = \frac{1}{2}\int_0^t e^{-\frac{1}{2}\xi_\pm(t-t')}\left[f^*(t') \pm f(t')\right]dt'. \tag{62}$$

We now proceed to calculate the Q function for the signal mode assumed to be initially in a coherent state. The Q function is expressible in terms of the antinormally ordered characteristic function as

$$Q(\alpha, \alpha^*, t) = \frac{1}{\pi^2}\int d^2\eta\,\phi_a(\eta^*, \eta, t)e^{\eta^*\alpha - \eta\alpha^*}. \tag{63}$$

Employing the identity

$$e^{\hat{A}}e^{\hat{B}} = e^{\hat{B}}e^{\hat{A}}e^{[\hat{A},\hat{B}]}, \tag{64}$$

the characteristic function $\phi_a(\eta^*, \eta, t)$ takes the form

$$\phi_a(\eta, \eta^*, t) = exp\left[-a(t)\eta^*\eta - \frac{b(t)}{2}(\eta^2 + \eta^{*2}) \right.$$
$$\left. +(F_+(t)\eta - F_-(t)\eta^*)\alpha_0^* - (F_+(t)\eta^* - F_-(t)\eta)\alpha_0 \right], \tag{65}$$

in which

$$a(t) = 1 - \frac{\varepsilon}{(\kappa + 2\varepsilon)}[1 - e^{-(\kappa+2\varepsilon)t}] + \frac{\varepsilon}{(\kappa - 2\varepsilon)}[1 - e^{-(\kappa-2\varepsilon)t}] \tag{66}$$

and

$$b(t) = \frac{\varepsilon}{(\kappa + 2\varepsilon)}[1 - e^{-(\kappa+2\varepsilon)t}] + \frac{\varepsilon}{(\kappa - 2\varepsilon)}[1 - e^{-(\kappa-2\varepsilon)t}]. \tag{67}$$

Finally, substituting (65) into Eq. (63) and then carrying out the integration, the Q function for the signal mode is found to be

$$Q(\alpha, \alpha^*, t) = \frac{q(t)}{\pi}exp\left[-u\alpha^*\alpha - \frac{v}{2}(\alpha^2 + \alpha^{*2}) + p(t)\alpha + p^*(t)\alpha^* \right], \tag{68}$$

in which

$$q(t) = [u^2 - v^2]^{\frac{1}{2}}exp\left[-\left(u(F_+^2(t) + F_-^2(t)) + 2vF_+(t)F_-(t)\right)\alpha_0^*\alpha_0 \right.$$
$$\left. -uF_+(t)F_-(t)\left(\alpha_0^2 + \alpha_0^{*2}\right) - \frac{v}{2}(F_+^2(t) + F_-^2(t))\left(\alpha_0^2 + \alpha_0^{*2}\right) \right], \tag{69}$$

$$p(t) = u\left(F_+(t)\alpha_0^* + F_-(t)\alpha_0\right) + v\left(F_+(t)\alpha_0 + F_-(t)\alpha_0^*\right), \tag{70}$$

with

$$u(t) = \frac{a(t)}{a^2(t) - b^2(t)} \tag{71}$$

and

$$v(t) = \frac{b(t)}{a^2(t) - b^2(t)}. \tag{72}$$

We find the Q function for the signal mode initially in a vacuum state upon setting $\alpha_0^* = \alpha_0 = 0$ to be

$$Q(\alpha, \alpha^*, t) = \frac{[u^2 - v^2]^{\frac{1}{2}}}{\pi} exp\left[-u\alpha^*\alpha - \frac{v}{2}(\alpha^2 + \alpha^{*2}) \right]. \tag{73}$$

One can easily check that the Q functions described by Eqs. (68) and (73) are normalized to unity.

III. THE DENSITY OPERATOR

Here we seek to determine the density operator for the signal mode. Suppose $\hat{\rho}'(\hat{a}^\dagger, \hat{a})$ is density operator for a certain light beam. Then upon expanding this density operator in normal order

$$\hat{\rho}'(t) = \sum_{kl} C_{kl}\hat{a}^{\dagger k}\hat{a}^l \tag{74}$$

and employing the completeness relation for coherent state

$$\int \frac{d^2\alpha}{\pi} |\alpha\rangle\langle\alpha| = \hat{I}, \tag{75}$$

one easily finds

$$\hat{\rho}'(t) = \frac{1}{\pi} \int d^2\alpha \sum_{kl} C_{kl}\alpha^{*k} |\alpha\rangle\langle\alpha|\hat{a}^l. \tag{76}$$

Thus in view of the identity

$$|\alpha\rangle\langle\alpha|\hat{a}^l = \left(\alpha + \frac{\partial}{\partial\alpha^*} \right)^l |\alpha\rangle\langle\alpha|, \tag{77}$$

there follows

$$\hat{\rho}'(t) = \int d^2\alpha Q\left(\alpha^*, \alpha + \frac{\partial}{\partial\alpha^*}, t \right) |\alpha\rangle\langle\alpha|, \tag{78}$$

where

$$Q\left(\alpha^*, \alpha + \frac{\partial}{\partial\alpha^*}, t \right) = \frac{1}{\pi} \sum_{kl} C_{kl}\alpha^{*k} \left(\alpha + \frac{\partial}{\partial\alpha^*} \right)^l. \tag{79}$$

IV. THE GLOBAL MEAN PHOTON NUMBER

Here we wish to calculate the mean photon number for the one-mode subharmonic light. The mean photon number, for the cavity light, is defined by

$$\bar{n} = \langle\hat{a}^\dagger(t)\hat{a}(t)\rangle. \tag{80}$$

Employing Eq. (73), the mean photon number of the signal mode is given by

$$\bar{n} = -\frac{\varepsilon}{(\kappa + 2\varepsilon)}[1 - e^{-(\kappa+2\varepsilon)t}] + \frac{\varepsilon}{(\kappa - 2\varepsilon)}[1 - e^{-(\kappa-2\varepsilon)t}]. \tag{81}$$

Thus at steady state we see that

$$\bar{n}_{ss} = \frac{4\varepsilon^2}{\kappa^2 - 4\varepsilon^2}. \tag{82}$$

We observe that the mean photon number given by (82) is twice that of a twin signal light beam.

V. The Local Mean Photon Number

We calculate the local mean photon number in a given frequency interval employing the power spectrum for the signal mode. The power spectrum for a cavity light with central frequency ω_0 is expressible as

$$P(\omega) = \frac{1}{\pi} Re \int_0^\infty \langle \hat{a}^\dagger(t)\hat{a}(t+\tau)\rangle_{ss} e^{i(\omega-\omega_0)\tau} d\tau. \tag{83}$$

The two-time correlation function for the cavity light can be written as

$$\langle \hat{a}^\dagger(t)\hat{a}(t+\tau)\rangle = Tr[\hat{\rho}'(t)\hat{a}^\dagger(0)\hat{a}(\tau)]. \tag{84}$$

Now introducing (78) into (84), we have

$$\langle \hat{a}^\dagger(t)\hat{a}(t+\tau)\rangle = \int d^2\alpha\, Q\left(\alpha^*, \alpha + \frac{\partial}{\partial\alpha^*}, t\right)\alpha^* Tr\left[\hat{\rho}'(0)\hat{a}(\tau)\right], \tag{85}$$

in which

$$\hat{\rho}'(0) = |\alpha\rangle\langle\alpha|. \tag{86}$$

We note that

$$Tr[\hat{\rho}'(0)\hat{a}(\tau)] = Tr[\hat{\rho}'(\tau)\hat{a}(0)]. \tag{87}$$

Furthermore, replacing (α, α^*, t) by $(\lambda, \lambda^*, \tau)$ in Eq. (78), the density operator $\hat{\rho}'(\tau)$ can be written as

$$\hat{\rho}'(\tau) = \int d^2\lambda\, Q(\lambda^*, \lambda + \frac{\partial}{\partial\lambda^*}, \tau)|\lambda\rangle\langle\lambda|. \tag{88}$$

Thus applying (88) in (87), we get

$$Tr[\rho'(\tau)\hat{a}(0)] = \int d^2\lambda\, Q\left(\lambda^*, \lambda + \frac{\partial}{\partial\lambda^*}, \tau\right)\lambda. \tag{89}$$

Moreover, replacing (α, α^*, t) by $(\lambda, \lambda^*, \tau)$ and $(\alpha_0, \alpha_0^*, t)$ by (α, α^*, τ) in Eq. (68), the $Q(\lambda, \lambda^*, \tau)$ function for the signal mode can be put in the form

$$Q(\lambda, \lambda^*, \tau) = \frac{q(\tau)}{\pi}exp\left[-u\lambda^*\lambda - \frac{v}{2}(\lambda^2 + \lambda^{*2}) + p(\tau)\lambda + p^*(\tau)\lambda^*\right]. \tag{90}$$

Thus combination of (85) and (90) leads to

$$\langle \hat{a}^\dagger(t)\hat{a}(t+\tau)\rangle = \frac{\varepsilon}{(\kappa-2\varepsilon)}e^{-\frac{1}{2}(\kappa-2\varepsilon)\tau} - \frac{\varepsilon}{(\kappa+2\varepsilon)}e^{-\frac{1}{2}(\kappa+2\varepsilon)\tau}. \tag{91}$$

Finally, substituting (91) into Eq. (83) and then carrying out the integration over τ, the power spectrum of the signal mode turns out to be

$$P(\omega) = \overline{n}\left\{ \frac{(\kappa^2 - 4\varepsilon^2)}{8\pi\varepsilon}\left[\left(\frac{1}{\Omega^2 + (\frac{\kappa-2\varepsilon}{2})^2} \right) - \left(\frac{1}{\Omega^2 + (\frac{\kappa+2\varepsilon}{2})^2} \right) \right] \right\}, \tag{92}$$

where $\Omega = \omega - \omega_0$.

We thus realize that the steady-state local mean photon number in the interval between $\omega' = -\lambda$ and $\omega' = \lambda$ can be written as
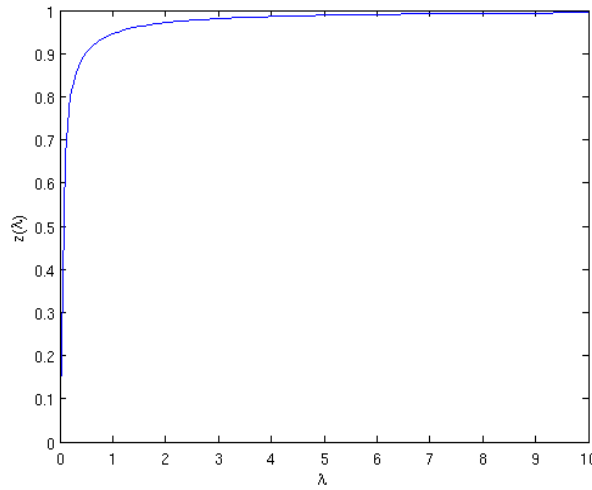
Figure 1: A plot of $z(\lambda)$ [Eq. (96)] versus λ for κ=0.8 and $\varepsilon = 0.35$.

$$\overline{n}_{\pm\lambda} = \int_{-\lambda}^{\lambda} P(\omega')d\omega', \tag{93}$$

where $\omega' = \omega - \omega_0$. Therefore, using (92) and (93) and the fact that

$$\int_{-\lambda}^{+\lambda} \frac{d\omega'}{\omega'^2 + a^2} = \frac{2}{a}tan^{-1}\left(\frac{\lambda}{a} \right), \tag{94}$$

we readily obtain

$$\overline{n}_{\pm\lambda} = \overline{n}z(\lambda), \tag{95}$$

where

$$z(\lambda) = \frac{1}{2\pi\varepsilon}\left[(\kappa + 2\varepsilon)tan^{-1}\left(\frac{2\lambda}{\kappa - 2\varepsilon} \right) - (\kappa - 2\varepsilon)tan^{-1}\left(\frac{2\lambda}{\kappa + 2\varepsilon} \right) \right]. \tag{96}$$

One can easily get from Fig. 1 that $z(0.5) = 0.9019$, $z(1) = 0.9496$, $z(2) = 0.9713$, and $z(3) = 0.9815$. Then combination of this results with Eq. (95) yields $\overline{n}_{\pm0.5} = 0.9019\,\overline{n}$, $\overline{n}_{\pm1} = 0.9496\,\overline{n}$, $\overline{n}_{\pm2} = 0.9713\,\overline{n}$, and $\overline{n}_{\pm3} = 0.9815\,\overline{n}$. We immediately see that a large part of the total mean photon number is confined in a relatively small frequency interval.

VI.   Global Quadrature Squeezing

We now proceed to calculate the global quadrature squeezing of the one-mode subharmonic light. We can define the quadrature variance of the cavity signal mode by

$$(\Delta a\pm)^2 = 2 + \langle : \hat{a}_{\pm}(t), \hat{a}_{\pm}(t) : \rangle, \tag{97}$$

where

$$\hat{a}_+(t) = \hat{a}^{\dagger}(t) + \hat{a}(t) \tag{98}$$

and

$$\hat{a}_-(t) = i(\hat{a}^{\dagger}(t) - \hat{a}(t)), \tag{99}$$

are the plus and minus quadrature operators for the cavity light. The first term on the right hand-side of Eq. (97) represents the quadrature variance of the cavity vacuum-state. It is also the commutator of the annihilation and creation operators representing the signal mode. Then Eq. (97) can be put in the form

$$(\Delta a_{\pm})^2 = 2 + 2\langle \hat{a}^{\dagger}\hat{a} \rangle \pm \langle \hat{a}^{\dagger 2} \rangle \pm \langle \hat{a}^2 \rangle. \tag{100}$$

Thus combination of (81) and (100) yields

$$(\Delta a_{\pm})^2 = 2 \mp \frac{4\varepsilon}{(\kappa \pm 2\varepsilon)}\left[1 - e^{-(\kappa \pm 2\varepsilon)t}\right]. \tag{101}$$

We observe that the signal mode is in a squeezed state and the squeezing occurs in the plus quadrature.

To this end, we calculate the quadrature squeezing of the cavity signal mode relative to the quadrature variance of the cavity vacuum-state. We then define the quadrature squeezing of the cavity signal mode by

$$S_+ = \frac{2 - (\Delta a_{\pm})^2}{2}, \tag{102}$$

so that on account of (101), there follows

$$S_+ = \frac{2\varepsilon}{(\kappa + 2\varepsilon)}\left[1 - e^{-(\kappa + 2\varepsilon)t}\right]. \tag{103}$$

Moreover, on taking into account (103), we see that at steady-state and threshold

$$S_+ = \frac{1}{2}. \tag{104}$$

We then note that at steady state and at threshold there is a 50% global squeezing of the cavity signal mode below the cavity vacuum-state level.

VII. Local Quadrature Squeezing

Here we obtain the local quadrature squeezing of the signal mode employing the spectrum of quadrature fluctuations. We first define the spectrum of quadrature fluctuations for a given cavity light with central frequency ω_0 by

$$S_\pm(\omega) = \frac{1}{\pi} Re \int_0^\infty \langle \hat{a}_\pm(t), \hat{a}_\pm(t+\tau) \rangle_{ss} e^{i(\omega-\omega_0)\tau} d\tau, \tag{105}$$

in which

$$\hat{a}_+(t+\tau) = (\hat{a}^\dagger(t+\tau) + \hat{a}(t+\tau)) \tag{106}$$

and

$$\hat{a}_-(t+\tau) = i(\hat{a}^\dagger(t+\tau) - \hat{a}(t+\tau)). \tag{107}$$

Then in view of Eqs. (98), (99), (106), and (107) along with (105), we have

$$\langle \hat{a}_\pm(t), \hat{a}_\pm(t+\tau) \rangle = \Bigg[\pm \langle \hat{a}(t)\hat{a}(t+\tau) \rangle + \langle \hat{a}(t)\hat{a}^\dagger(t+\tau) \rangle$$
$$+ \langle \hat{a}^\dagger(t)\hat{a}(t+\tau) \rangle \pm \langle \hat{a}^\dagger(t)\hat{a}^\dagger(t+\tau) \rangle \Bigg]. \tag{108}$$

Following the same procedure employed as in section five, one can readily establish that

$$\langle \hat{a}(t)\hat{a}^\dagger(t+\tau) \rangle_{ss} = \frac{\varepsilon}{(\kappa - 2\varepsilon)} e^{-\frac{1}{2}(\kappa-2\varepsilon)\tau} - \frac{\varepsilon}{(\kappa + 2\varepsilon)} e^{-\frac{1}{2}(\kappa+2\varepsilon)\tau}, \tag{109}$$

$$\langle \hat{a}^\dagger(t)\hat{a}^\dagger(t+\tau) \rangle_{ss} = -\frac{\varepsilon}{(\kappa - 2\varepsilon)} e^{-\frac{1}{2}(\kappa-2\varepsilon)\tau} - \frac{\varepsilon}{(\kappa + 2\varepsilon)} e^{-\frac{1}{2}(\kappa+2\varepsilon)\tau}, \tag{110}$$

and

$$\langle \hat{a}(t)\hat{a}(t+\tau) \rangle_{ss} = -\frac{\varepsilon}{(\kappa - 2\varepsilon)} e^{-\frac{1}{2}(\kappa-2\varepsilon)\tau} - \frac{\varepsilon}{(\kappa + 2\varepsilon)} e^{-\frac{1}{2}(\kappa+2\varepsilon)\tau}. \tag{111}$$

Now on account of (91), (109), (110), and (111) together with (108), we find

$$\langle \hat{a}_\pm(t), \hat{a}_\pm(t+\tau) \rangle_{ss} = (\Delta a_\pm)^2_{ss} e^{-\frac{1}{2}(\kappa\pm2\varepsilon)\tau}. \tag{112}$$

Finally, introducing (112) into (105) and then carrying out the integration over τ, the spectrum of the quadrature fluctuations for the signal mode is found to be

$$S_\pm(\omega) = (\Delta a_\pm)^2_{ss} \left(\frac{\frac{(\kappa\pm2\varepsilon)}{2\pi}}{\Omega^2 + [\frac{\kappa\pm2\varepsilon}{2}]^2} \right), \tag{113}$$

where $\Omega = \omega - \omega_0$.

The local quadrature variance in the interval $\omega' = -\lambda$ and $\omega' = \lambda$ can then be written as

$$(\Delta a_{\pm\lambda})^2 = \int_{-\lambda}^{\lambda} (S_\pm(\omega'))^2 d\omega', \tag{114}$$
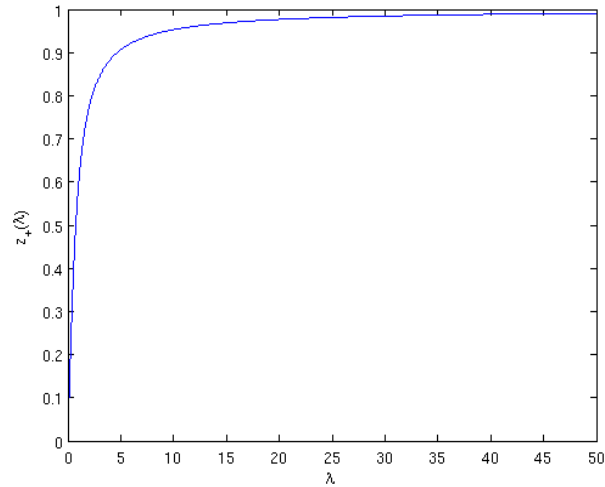
Figure 2: A plot of $z_+(\lambda)$ [Eq. 116] versus λ for κ=0.8 and $\varepsilon = 0.35$.

in which $\omega' = \omega - \omega_0$.

Then upon integrating Eq. (113) in the interval between $\omega' = -\lambda$ and $\omega' = \lambda$, using the relation described by (94), we readily get

$$(\Delta a_{\pm\lambda})^2 = \left(1 \mp \frac{2\varepsilon}{\kappa \pm 2\varepsilon}\right)\left[\frac{2}{\pi}tan^{-1}\left(\frac{2\lambda}{\kappa \pm 2\varepsilon}\right)\right], \tag{115}$$

in which

$$z_\pm(\lambda) = \frac{2}{\pi}tan^{-1}\left(\frac{2\lambda}{\kappa \pm 2\varepsilon}\right). \tag{116}$$

We easily obtain from Fig. 2 that $z(+5)$=0.906, $z(+15)$=0.968, $z(+25)$=0.981, and $z(+50)$=0.990. Then combination of this results with Eq. (115) yields $(\Delta a_{\pm 5})^2$=0.906 $(\Delta a_+)^2$, $(\Delta a_{\pm 15})^2$=0.968 $(\Delta a_+)^2$, $(\Delta a_{\pm 25})^2$=0.981 $(\Delta a_+)^2$, and $(\Delta a_{\pm 50})^2$=0.990 $(\Delta a_+)^2$. We immediately see that a large part of the quadrature variance of the signal mode is confined in a relatively small frequency interval.

We note that the quadrature variance of the vacuum state in the interval between $\omega' = -\lambda$ and $\omega' = \lambda$ can be obtained by setting $\varepsilon = 0$ in Eq. (115). We then get

$$(\Delta a_{\pm\lambda})_v^2 = (\Delta a_\pm)_v^2 z_v(\lambda), \tag{117}$$

where

$$z_v(\lambda) = \frac{2}{\pi}tan^{-1}\left(\frac{2\lambda}{\kappa}\right). \tag{118}$$

We next calculate the local quadrature squeezing of the signal mode relative to the local quadrature variance of vacuum state. We define the local quadrature squeezing of the cavity light in the interval between $\omega' = -\lambda$ and $\omega' = \lambda$ by

$$S_{\pm\lambda} = \frac{(\Delta a_{\pm\lambda})_v^2 - (\Delta a_{\pm\lambda})^2}{(\Delta a_{\pm\lambda})_v^2}. \tag{119}$$

Then combination of Eqs. (115), (117), and (119) leads to

$$S_{\pm\lambda} = 1 - \left(\frac{\kappa}{\kappa + 2\varepsilon}\right)\frac{tan^{-1}(\frac{2\lambda}{\kappa + 2\varepsilon})}{tan^{-1}(\frac{2\lambda}{\kappa})}. \tag{120}$$

We immediately see that the quadrature squeezing of the cavity light in a given frequency in-
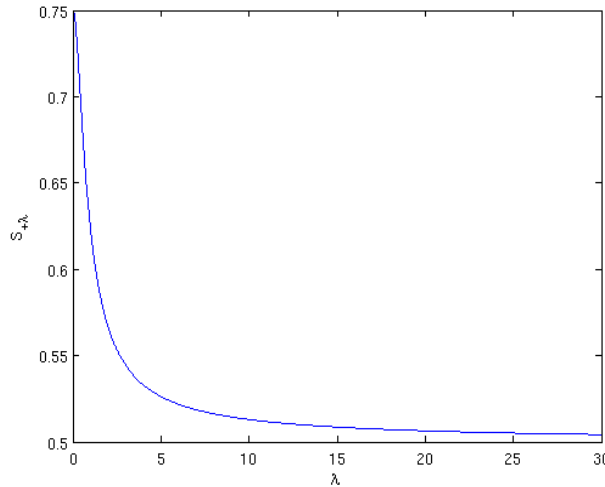
Figure 3: A plot of $S_{\pm\lambda}$ [Eq. 120] versus λ for κ=0.8 and $\varepsilon = 0.4$.

terval is not equal to that of the cavity light in the entire frequency interval. We see from the plot in Fig.3 that the maximum local quadrature squeezing is 75% and occurs in the ±0.01 frequency interval. In addition, we note that the local quadrature squeezing approaches to the global quadrature squeezing as λ increases.

VIII.   CONCLUSION

It has been established that the mean photon number of the signal mode, obtained following the usual procedure, is just half of the actual mean photon number. The mean photon number calculated, employing the usual procedure, is certainly the mean photon number of a twin signal light beam. In view of this we have asserted that the usual procedure of analysis is valid for a light mode represented in the pertinent Hamiltonian by first order annihilation and creation operators whose commutation relation $[\hat{a}, \hat{a}^\dagger]$=1.

Therefore, we have analyzed the photon statistics and quadrature squeezing of the signal mode applying the commutation relation $[\hat{a}, \hat{a}^\dagger]$=2. We have found that the mean photon number to be twofold of that of a twin signal light beam. And a large part of the mean photon number is confined in a relatively small frequency interval. In addition, we have shown that the local quadrature squeezing of the signal mode is in general greater than the global quadrature squeezing and approaches to the global quadrature squeezing as λ increases . Moreover, the one-mode subharmonic light beams have a maximum squeezing of 75% below the vacuum state level and occurs in ±0.01 frequency interval.

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Assessing the Efficient Utilization of Electricity by Domestic Consumers in the Agona District

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Abstract- The study assessed the efficient utilization of electricity by domestic consumers in the Agona District. Descriptive survey design was employed in the study. Purposive and simple random sampling techniques were used in selecting five (5) towns and 100 respondents, respectively. A questionnaire as well as interview and observation methods were used in data collection. The data obtained from respondents were analyzed using frequencies and percentages. The study revealed that almost two-thirds (63%) of the respondents in the condominium consume electricity from a single central credit meters. Again, the study showed that lack of access to energy efficient technologies have contributed to the waste of electricity in the households. The results also revealed that consumers have little or no knowledge about some basic energy conservation tips. It is recommended that all households in such condominium should be provided with separate meters preferably the pre-paid meters so as to encourage consumers to conserve energy.

Keywords: condominium; credit meters; pre-paid meters; electricity bills.

GJSFR-E Classification : FOR Code : 299901

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Strictly as per the compliance and regulations of :

Assessing the Efficient Utilization of Electricity by Domestic Consumers in the Agona District

Enock Andrews Duodu α & J. D. Owusu-Sekyere σ

Abstract- The study assessed the efficient utilization of electricity by domestic consumers in the Agona District. Descriptive survey design was employed in the study. Purposive and simple random sampling techniques were used in selecting five (5) towns and 100 respondents, respectively. A questionnaire as well as interview and observation methods were used in data collection. The data obtained from respondents were analyzed using frequencies and percentages. The study revealed that almost two-thirds (63%) of the respondents in the condominium consume electricity from a single central credit meters. Again, the study showed that lack of access to energy efficient technologies have contributed to the waste of electricity in the households. The results also revealed that consumers have little or no knowledge about some basic energy conservation tips. It is recommended that all households in such condominium should be provided with separate meters preferably the pre-paid meters so as to encourage consumers to conserve energy. Also, consumers are to use modern appliances with energy efficient standards and label codes. Finally, energy conservation tips should be known and practiced by all the domestic consumers of electricity.

Keywords: condominium; credit meters; pre-paid meters; electricity bills.

I. Introduction

Electricity supply in Ghana suffered a serious decline as a result of several factors but mainly due to poor inflows for water into the Volta basin, which until then accounted for 95% of Ghana's electricity supply. Industry including the Volta Aluminum Company (VALCO) accounts for the largest consumption of electricity in the country. VALCO alone takes about 59% of total electricity consumption. After the industrial sector has taking 79% of the country's total electricity consumption, the residential, commercial and government sector account for the remaining 21% (Energy Foundation, 1999).

Until recently, Ghana's total energy requirement was produced from hydro generation. This is now complemented by thermal generation and imports. For example, in 1999 Volta River Authority (VRA) produced the total energy requirement of the country with 60% from hydro generation 25% from thermal generation and 15% import from La Cote d'Ivoire (Donkor, 2001).

Though power from hydro plants is relatively cheap to produce, its availability depends on the rainfall

pattern, hence the need to diversify supply base from hydro to other bases such as thermal power system. Such an approach could help minimize the effect of decline in electricity generation resulting from drought in the Volta River basin, forcing the power utilities to embark on a power curtailment exercise, which adversely affect the economic growth of the country.

According to VRA (2001), the authority operates a total installed power generation capacity of 1,432MW. This is made up of two hydro-electric plants on the Volta River with installed capacities of 912 MW at Akosombo and 160MW at Kpong, a 30MW diesel plant at Tema, and a 330MW combined cycle thermal power plant at Takoradi.

II. Background to The Study

The annual growth in the demand for electrical energy before 1986 was low as 2%. However, for the period 1986 –1997, Ghana moved into a higher energy consuming bracket with a 10-15% annual demand growth rate. The phenomenal growth in the demand for electricity was mostly due to the economic policies of the 1980's (economic recovery programme and structural adjustment programme) which brought about profound changes – production level of factories going up and new private enterprise opening by the day in every community which need to be connected to the national grid. Also, at the current annual growth rate of 10-15%, the demand for electricity energy is expected to increase to at least seven times (7x) the present level of demand by the year 2020. However, Ghana lacks the energy resources to satisfy the ever-increasing demand, building new power capacity plants is extremely expensive and the need to import fuel to run new thermal plants is also not an attractive option. Report by Donkor (2001) indicated that in 1998, Ghana imported electrical energy from Cote d'Ivoire at much higher cost than is available domestically due to inability to produce sufficient electrical energy.

Research conducted by Energy Foundation (1999) observed that it has been estimated that the level of waste in the use of electrical energy by consumers is over 20%, indicating that consumers waste the entire generation of Kpong hydro power plant. This is due to the use of obsolete equipment, inadequate maintenance on appliances and lack of knowledge about the very steps that can be taken to improve the efficient use of electrical energy.

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a) *Statement of the Problem*

Electrical energy is one of the pre-requisite for national development. As the government is doing all it can to ensure an uninterrupted power supply for industrial and commercial consumers, there is a need to save energy as much as possible. For example, in March 2003 an increase in electricity tariff in the country saw many domestic consumers paying huge electricity bills; however, consumers are ignorant about how to use electricity efficiently to reduce their energy consumption. As stated by a consumer "why do I consumed so much of electricity and pay so much".

b) *Purpose of the Study*

The purpose of the study was to assess the efficient utilization of electricity by domestic consumers in the Agona District. Again, to evaluate the benefits derived from judicious use of energy by consumers.
The key issues of the study were therefore to find out;

i. The consumption pattern of electrical appliances.

ii. The availability of energy efficient technology.

iii. The energy saving tips and measures.

c) *Research Questions*

The research questions that guided the study were as follow:

1. What methods of billing systems are being employ by service providers?
2. How do consumers know that an appliance is energy efficient?
3. What strategies can be put in place to reduce the waste of electricity consumption in the households?

d) *Significance of the Study*

The study aimed at finding out how energy is dissipated by domestic consumers. It will also help to identify the most suitable practices and measures to put in place to reduce energy in the households. Moreover, it would help erase the erroneous impression consumers have on the staff of ECG as thieves thinking that the huge bills they pay are due to illegal increment of bills. Finally, the study may serve as an operative level for further research into certain aspect of the efficient use of electricity.

III. Methodology

a) *Study Area*

The Agona District is situated in the eastern portion of the central region with a total land size of 540sq km and a population of about 15,8995(GSS, 2001). The district is bordered on the east by Awutu-Effutu-Senya District; on the west by Asikuma-Odoben-Brakwa District; on the north east by Akim West District; on the north west by Birim South District and to the south by the Gomoa District with Agona Swedru as the district capital. The district has 862 settlements with 11 urban towns; and out of the total settlements, only 15 have been connected to the national electricity grid (AgonaDistrict, 2003). The first public electricity supply in the district commenced in 1947 from a diesel generating plant and in 1967 when the hydro plant at Akosombo became operational, the power station was linked to the national electricity grid of VRA (http://www.-ecgonline.info/index.php/organisation/about-us. Retrieved February 1, 2002.).

b) *Research Design*

A descriptive research design of the survey type was adopted for this study.

i. *Population and Sampling Procedure*

The target population for this study was all the domestic consumers of electricity in the Agona District of the Central Region. The sample for the study was limited to five (5) towns in the district. Purposive random sampling method was used to select the towns; these included Swedru, Nyakrom, Kwanyako, Nsaba and Duakwa. Twenty (20) respondents from each of the towns were randomly selected.

c) *Instrumentation*

The data collection instrument included questionnaire, interview and observation schedules. The questionnaire was administered by the researcher to the respondents and the return rate was 95%.For the interview section, the researcher posed the questions and the responses given were written in a note book. Finding from observations were also recorded.

d) *Data Analysis*

Frequencies and simple percentages were used to analyze the data of the study. A narrative summary including direct quotes was made to further explain the data.

IV. Results

a) *Research Question 1*

This section ascertains the billing systems employed on the consumers by the service providers. The result in table 1 shows that more than half 66 (69%) of the respondents live in the compound houses while 29 (21%) live in bungalows.

Table 1 : Type of dwellings

Type	Frequency	Percentage %
Compound house (rooms)	66	69.0
Flat/Apartment	29	21.0
Total	**95**	**100.0**

Source: Field Data, 2003

The data in table 2 records that all 95(100%) of the respondents consume energy from credit meters with no respondent calibrates with prepaid meter.

Table 2 : Method of billing systems

Method	Frequency	Percentage %
Credit meter	95	100.0
Prepaid meter	-	-
Total	95	100.0

Source: Field Data, 2003

The statistics in figure 1 illustrate that 16% of consumers monitor their meter readings daily, 32% check their consumptions weekly, 42% monitor consumptions monthly while10% never check their energy consumption pattern.
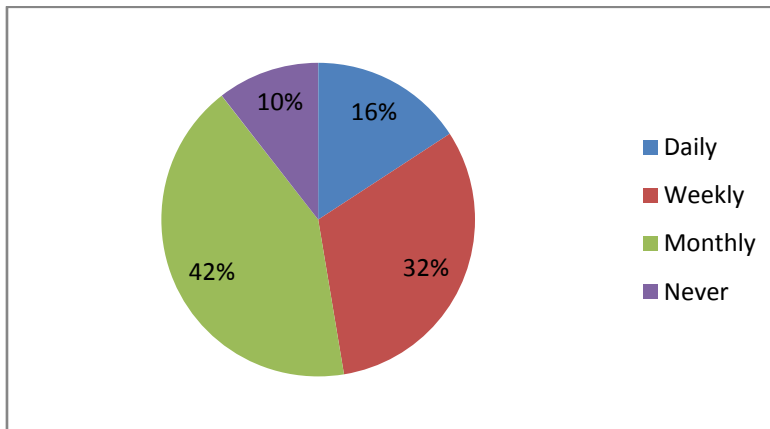
Figure 1 : Monitoring of Energy Consumption
Source: Field Data, 2003

The data in table 3 indicates that only 10 (11%) of the respondents fall within the 0-50 kWh consumption brackets while 40 (42%) and 45 (47%) consumers fall within the 51-300 kWh bracket and300+ kWh bracket, respectively.

Table 3 : Energy consumption bracket of consumers

Consumption bracket (kWh)	Frequency	Percentage %
0 – 50kWh	10	11.0
51 – 300kWh	40	42.0
300+ kWh	45	47.0
Total	95	100.0

Source: Field Data, 2003

The information in figure 2 shows that majority 80 (84%) of the respondents pay their own bills while 15 (16%) of the consumption borne by their employers.
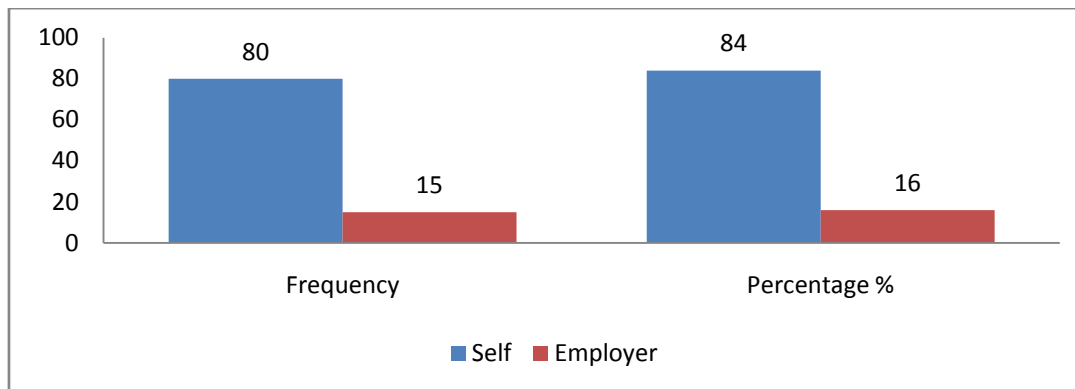
Figure 2 : Mode of Payment of Electricity Bills
Source: Field Data, 2003

The result in table 4 postulates that majority 80 (84%) of the respondents share bills according to the number of points with 10 (11%) and five (5%) share tariff according to number of rooms and size of the households, respectively.

Table 4 : Method of sharing electricity bills

Method	Frequency	Percentage %
No. of point(s)	80	84.0
No. of room(s)	10	11.0
Size of household(s)	5	5.0
Total	95	100.0

Source: Field Data, 2003

The information in table 5 records that almost all 85 (89%) of the respondents submit that they do not know their appliance energy consumptions with only 10 (11%) indicate that they do know their appliance ratings.

Table 5 : Knowledge of consumption rate of household appliances

Response	Frequency	Percentage %
Yes	85	89.0
No	10	11.0
Total	95	100.0

Source: Field Data, 2003

b) Research Question 2

This section finds out some of the energy efficient technologies and practices being use by domestic consumers. The data in table 6 shows that majority 80 (84%) of consumers strongly agree that energy efficient technologies be made accessible to consumers as well as the purchase of energy efficient appliances while few 15 (16%) opposed to the assertions. All 95 (100%) of the respondents strongly agree that electrical appliance importers and manufacturers conformed to energy efficient standards and codes. About three-fifth 65 (68%) of the population strongly affirmed that second hand electrical appliances consume more electrical energy than the modern type as compare to 30 (32%) who disagree to the response. More than three-forth 80 (84%) of respondents strongly agreed that television sets must be put off when nobody is watching with only 15 (16%) opposing the assertion. All 95 (100%) of consumers strongly agree that lights should be put off when not in use. More than half 60 (63%) of the respondents strongly disagree that the doors to refrigerators be opened frequently while 35 (37%) agree to the statement. The data also shows that all 95 (100%) of consumers strongly agree that consumption rates in the households must be monitored.

Table 6 : Energy efficient technology and practices

S/N	Statements	Responses			
		SA/A		SD/D	
		Freq.	%	Freq.	%
1	Energy efficient technologies should be made accessible to consumers	80	84	15	16
2	It is good to purchase energy efficient appliances	80	84	15	16
3	Electrical appliance importers and manufacturers should conform to energy efficient standards and codes	95	100	-	-
4	Second hand electrical appliance consumes more energy	65	68	30	32
5	Television should be put off when nobody is watching	80	84	15	16
6	Light should be put off when not in use	95	100	-	-
7	Refrigerator doors should be opened frequently	35	37	60	63
8	It is important to monitor how electricity is use in the households	95	100	-	-

SA= Strongly Agree, A= Agree, SD= Strongly Disagree, D= Disagree
Source: Field Data, 2003

c) *Research Question 3*

This section finds out the strategies which can be put in place to minimize waste of electricity in the households.

The study in table 7 shows that one-third 20 (21%) of the respondents do iron their clothes daily while 40 (42%) iron their clothes twice in a week with 35 (37%) iron their clothes once in a week.

Table 7 : Rate of ironing clothes

Rate	Frequency	Percentage %
Daily	20	21.0
Twice weekly	40	42.0
Weekly	35	37.0
Total	95	100.0

Source: Field Data, 2003

The result in table 8 records that less than one-third 25 (26%) of the respondents defrost their refrigerators weekly; more than half 30 (32%) and 35 (37%) defrost their refrigerators monthly and quarterly, respectively, however, only five (5%) do not defrost the apartment at all.

Table 8 : Rate of defrosting refrigerators

Rate	Frequency	Percentage %
Weekly	25	26.0
Monthly	30	32.0
Quarterly	35	37.0
Never	5	5.0
Total	95	100.0

Source: Field Data, 2003

The statistics in figure 3 suggest that less than quarter 15 (16%) and 35 (37%) of the consumers use 25W and 40W incandescent bulbs lavatories respectively, while 40 (42%) and five (5%) use the 40W and 100W incandescent bulbs respectively.
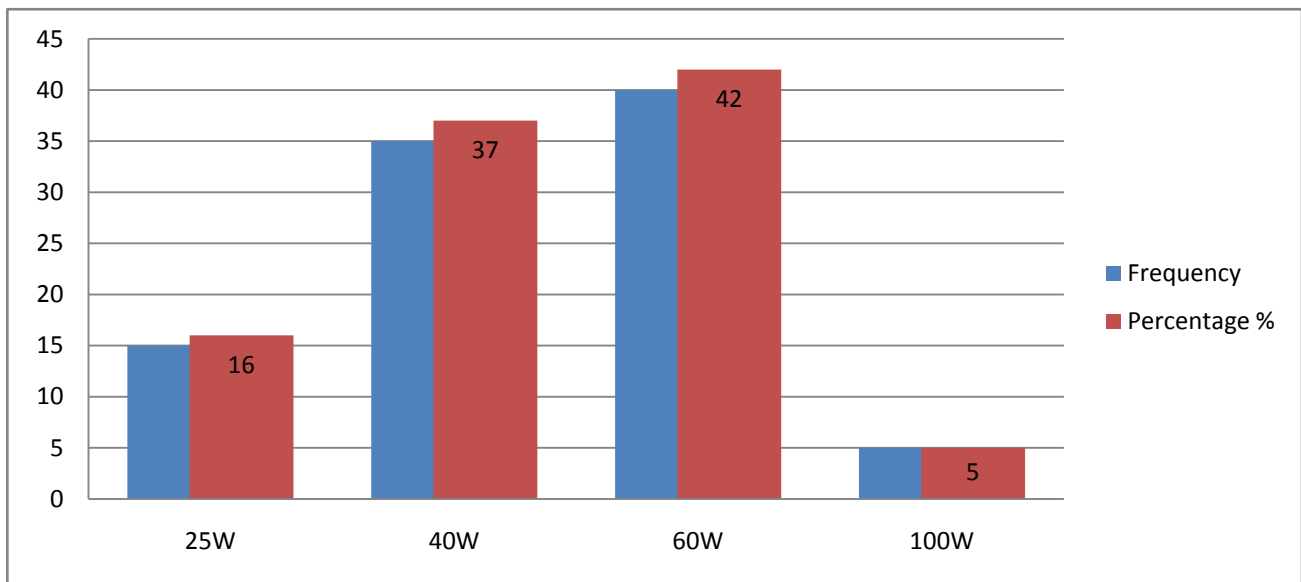
Figure 3 : Type of Incandescent Bulbs Use in Lavatories

Source: Field Data, 2003

The data in table 9 shows that out of the 700 lamps indicated by consumers, more than two-thirds 550 (79%) use incandescent lamps, 100 (14%) use fluorescent lamps with only 50 (7%) using compact fluorescent lamps (CFLs) for lighting.

Table 9 : Type and number of lamps in the households

Lamp	Quantity	Percentage %
Incandescent	550	79.0
Fluorescent	100	14.0
CFL	50	7.0
Total	**95**	**100.0**

Source: Field Data, 2003

V. DISCUSSION

The study revealed that most compound houses have been bridged to a central bulk meters which tend to force condominium electricity users into high consumption bracket, hence end up paying huge amount of electricity bills. Under such circumstances, consumers who feel that they pay more than they consume deliberately waste energy. Also, some consumers may waste energy since they know that others will pay for the waste. However, when consumers only pay for what they use they tend to be more conservative and every resident become an active participant in energy management of the condominium or institution (ECG, 2002: February; Schwaller and Gilberti, 1996).The finding confirms the assertion made by ECG (2002: August), Donkor (2001) and Energy Foundation (n.d) that lack of individual electricity meters to monitor the exact amount of electricity used by consumers encourages waste. The research added that though the progressive tariff structure could discourage waste by the rich, however it could also be a burden for consumers sharing common meters. This is because a condominium with a number of families may have a higher meter reading causing them to pay more per unit of electricity consumed. This presupposes that if each household in condominium is provided with separate credit meters, preferably pre-paid meters instead of central credit meters, consumption can be monitored and reduced, thereby conserving energy waste (VRA, 2003; 2002; ECG, 2002: June; Energy Commission, 1999).

The study further revealed that old equipment and appliances waste energy. This confirms report by Donkor (2001) and ECG (2002: July) that modern equipment such as lighting systems, air conditioners, refrigerators, cookers, washing machines and heating systems reduce energy consumption by 20% compared with standard ones. The study added that compact fluorescent lamps consume less energy and last longer as compared to the incandescent lamps of the same wattage. The research proved that currently no energy efficient standards and label codes laws to ensure that only energy efficient technologies are imported and sold in the country (Energy Foundation, n.d). This situation has led to the dumping of inefficient and obsolete technologies on the Ghanaian market and almost all the used appliances such as air conditioners, refrigerators and motors imported into the country are inefficient in every use and have been condemned in their country of origin therefore their high use has contributed to excess consumption of energy in the country.

The study also shows that consumers have little or no knowledge about some common energy conservation tips. This buttresses research conducted by Donkor (2001) and ECG (2003: January) that practicing simple conservation tips could have a significant effect in the residential and commercial facilities to reduce energy consumption in the area of audio-visual appliances, lighting, refrigeration and heating systems.

VI. CONCLUSIONS

Evidence from the study indicates that majority of households in the condominium are using central credit meters instead of separate credit meters or the pre-paid meters. Feedbacks from respondents suggested that lack of access to energy efficient technologies have contributed to the waste of electricity, hence, the need to use modern efficient appliances and the enforcement of energy efficient codes and standards on end-use products. It was emerged from the study that consumers have little or no knowledge about some basic energy conservation tips.

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The Chemical Constituents and Biological Activities of Stem Bark Extract of *Theobroma Cacao*

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Abstract- The chemical composition of the extract of the stem bark of *Theobroma cacao* and its biological activity is hereby studied. Dried pulverised stem bark extract of *Theobroma cacao* was batch extracted with ethanol. This crude ethanol extract was screened for the presence of plant chemicals: the result showed the presence of alkaloid, tannin, saponin, glycoside, phenol, flavonoid and carboxylic acid. Four human pathogens; *Escherichia coli*, *Pseudomonas aeruginosa*, *Streptococcus pnemoniae* and *Staphylococcus aureus* were used in the test for the biological activity and were discovered to be susceptible to the crude extract. The extract was acidified with concentrated hydrochloric acid (HCl) and extracted with chloroform ($CHCl_3$). The organic layer was basified with 1 M sodium hydroxide (NaOH) solution and the alkaline layer treated with HCl.

Keywords: activity, bark, chemicals, extract, pathogens, stem.

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THECHEMICALCONSTITUENTSANDBIOLOGICALACTIVITIESOFSTEMBARKEXTRACTOFTHEOBROMACACAO

Strictly as per the compliance and regulations of :

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Nwokonkwo D. C.[α] & Okeke, G. N.[σ]

Abstract- The chemical composition of the extract of the stem bark of *Theobroma cacao* and its biological activity is hereby studied. Dried pulverised stem bark extract of *Theobroma cacao* was batch extracted with ethanol. This crude ethanol extract was screened for the presence of plant chemicals: the result showed the presence of alkaloid, tannin, saponin, glycoside, phenol, flavonoid and carboxylic acid. Four human pathogens; *Escherichia coli*, *Pseudomonas aeruginosa*, *Streptococcus pnemoniae* and *Staphylococcus aureus* were used in the test for the biological activity and were discovered to be susceptible to the crude extract. The extract was acidified with concentrated hydrochloric acid (HCl) and extracted with chloroform (CHCl₃). The organic layer was basified with 1 M sodium hydroxide (NaOH) solution and the alkaline layer treated with HCl. The acidic component showed strong presence of tannin, saponin, phenol, alkaloid, mild presence of flavonoid and glycoside. The minimum inhibitory concentration (MIC) against the pathogens was at a concentration of 1×10^{-8} M for *Escherichia coli*, *Pseudomonas aeruginosa* and approximately 1×10^{-6} M for *Streptococcus pnemoniae* and *Staphylococcus aureus*. The inhibition zone diameter (IZD) was carried out at different concentrations of the plant extract. The concentration at 12.5 mg/mL was significant for all the microorganisms.

Keywords: activity, bark, chemicals, extract, pathogens, stem.

I. INTRODUCTION

The use of herbal medicines to cure/prevent illness and to lubricate the wheels of social interaction is a behaviour which antedates civilization and is present in every society irrespective of its level of sophistication (Sanjay and Yogeshwer, 2003). The drugs of today's modern society are products of research and development, whose raw materials are naturally occurring materials which are obtained from plants; either in the roots stems, leaves, fruits and seeds (Odugbemi, Akinsulire, 2006; Burkill, 1994).

Up till now, some of the widely used drugs of plant origin are still produced by extraction from plants though, for some, their chemical structures are known and the methods developed for their laboratory synthesis (Warren, 2002).

The cost of synthesis is high, therefore it is cheap and easier to access the plant chemical and in most cases, the natural product is better with minimal side effects compared to the synthetic ones (Xu and Zhao, 2004). As such despite the chemical structures currently available for the screening for the actions of therapeutic value, natural products of plants origin remain a most important source of new drugs. The majority of bioactive compounds are terpenoids, steroids, alkaloids, organic acids, polyketides, macrolides, pyranones, glycosides, phenolic compounds and derivatives. These compounds exhibit antibiotic, antitumour, antiviral, anti-inflammatory, immunomodulatory, enzyme inhibiting, cardiovascular, analgesic, antidiabetic, antioxidant, insecticidal, nematocidal e.t.c effects. Globally plants extracts are employed for their antibacterial, antifungal, antiviral, antihypertensive activities (Meyer et al., 1996; Xu and Zhao, 2004).

The continuous evolution of bacteria resistant to currently available antibiotics has been the main drive in the search for novel and more effective compounds that are bactericidal, and the focus is on plants because of their use historically and the fact that many people the world over rely on them for the treatment of infectious and non-infectious diseases (Martinez, et al., 1996). These plant chemicals were/are isolated from a wide array of plants and even those plants already known are being discovered of having new and interesting physiological properties, take *Theobroma cacao* (Wood and Lass, 1985) as an example.

The *Theobroma cacao* tree is a source of the world's most delicious and familiar products, chocolate. Chocolate which is gotten from the seeds of this plant contains so many valuable a compound amongst which is theobromine, a useful antioxidant.

In this study, the stem bark of *Theobroma cacao* was investigated; ethanol was used as the solvent for the extraction. The ethanol extract was screened for the presence and type of plant chemicals and whether *Escherichia coli*, *Pseudomonas aeruginosa*, *Streptococcus faecalis* and *Staphylococcus aureus* have intermediate or strong resistant/susceptibility to the extract.

II. GENERAL EXPERIMENTAL PROCEDURES

Weighing was done on a weighing balance model 770Mak Kew and Mettler P1210; grinding was

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carried out using electric grinding machine model EC-101 Binatone. All reagents were of analytical grade; Mueller- Hinton agar was used for the biological activity of the sample. Authentic sample of the micro organisms were obtained from the Department of Applied Microbiology Ebonyi State University Abakaliki, Nigeria.

a) Plant Material

One kilogram (1kg) of fresh stem bark sample was obtained from Enugu, Enugu State Nigeria and authenticated in the Applied Biology Department, Ebonyi State University Abakaliki. The plant sample was washed to remove lichen, fungus and sand then oven dried at a temperature of 80° C for seven days.

b) Extraction

Five hundred grams (500 g) of the dried sample were ground into powder and soaked by soaking and percolation method in 2 x 1000 mL $CHCl_3$ (BDH, England) for 98 h. The chloroform extract was removed by filtration and the solution evaporated to dryness to reveal 123 g of a brown amorphous gel. This crude sample was screened for the presence and type of plant chemicals.

i. Alkaloids

Dragendorf's reagent, a solution of potassium bismuth iodide was used to determine the presence of alkaloids. About 0.85 g of bismuth nitrate (BDH, England), was dissolved in 10 mL of 0.5 M NaOH(Arondale, England), to this was added 10 mL of glacial acetic acid (BDH, England), and 40 mL of distilled water; this was labeled solution 1. Solution 2 was prepared by mixing 8 g of potassium iodide and 20 mL distilled water. Approximately 1 mL of each of solutions 1 and 2 were mixed with 2 mL of glacial acetic acid, 10 mL of water and 1 mL of 2 g plant sample (which was prepared by dissolving 2 g plant extract in 30 mL of distilled water). A brownish-yellow coloured mixture was obtained.

ii. Flavonoids

One grams (1 g) plant sample was dissolved in 2 mL methanol (BDH, England), to this was added 100 mg magnesium powder (Sigma-Aldrich, USA), and shaken. Three (3) drops of conc. HCl (BDH, England) was added, a red colouration developed within 2 min of the addition of the acid
(Xu, 2012; Ikan,1991).

iii. Phenols

a. Iron (III) Chloride Solution Test

About 50 mg of the plant sample was dissolved in 1 mL of water, to this was added 1 drop of neutral 1 % $FeCl_3$ (BDH, England) solution and shaken. After 2-3 sec, 0ne more drop of the ferric solution was added. A purple colour was observed (Furnis, et al., 2006).

b. Phthalein Test

Approximately 500 mg of the plant sample and 500 mg of phthalic anhydride (Sigma-Aldrich, USA) were mixed intimately in a test tube and 1 drop of conc. H_2SO_4 (BDH, England), added. The reaction test tube was allowed to stand for 5 min in a 50 mL beaker of hot paraffin oil. The test tube was removed and allowed to cool. Four (4) mL of 5 % NaOH was added and stirred until the fused mixture dissolved. This was diluted with 4 mL distilled water and filtered. A red colour was observed.

iv. Tannins

a. KOH Test

Ten (10) mg of the extract was added to 1 mL of freshly prepared 10 % KOH, a dirty precipitate was observed (Sofowora, 1984; Harborne, 1973; Nwokonkwo, 2009)

b. Iron (III) Chloride Solution Test

Three (3) drop of 5 % FeCl3 solution was added to a solution of 1 mL of plant extract prepared by dissolving 20 mg plant sample in 10 mL of water. Two (2) mL of water was added to the whole mixture, a greenish precipitate was obtained.

v. Saponins

Ten (10) mg of plant material was introduced into a 50 mL conical flask, to this was added 20 mL of distilled water and shaken vigorously, there was a lasting bubble effect after the agitation. Three (3) drop of arachis oil was added to the frothing mixture obtained from above; a stable emulsion developed.

vi. Glycosides

Five (5) mL of 50 % H_2SO_4 was added to 5 mL of the extract (100 mg extract in 10 mL water) and heated for 15 min and allowed to cool. To this was added 5 mL of Fehling's solution and boiled for 5 min, a brick red precipitate was observed.

vii. Carboxylic Acid

200 mg of sample was dissolved in 5 mL of ethanol and 1 mL conc. H_2SO_4 and warmed for 2 min. This was cooled and poured cautiously into 4 mL 0.5 M solution of sodium carbonate in an evaporating dish. A sweet fruity smell of an ester was perceived.

viii. Preparation of Acidic Component

Approximately 2 g of plant sample was dissolved in 20 mL of HCl and extracted with 2 x 30 mL $CHCl_3$ using a separatory funnel. The $CHCl_3$ layer was treated with with 30 mL of 1 M NaOH solution. The aqueous alkaline layer was treated with 30 mL of 0.5 M HCl and the resulting solution evaporated to dryness to reveal a light brown gel which was used for the biological test. The preliminary phytochemical tests of the residue showed the presence of saponin, phenol, flavonoid, tannin and carboxylic acid (Ejele and Alinor, 2010; Ejele and Nwokonkwo, 2013).

c) Biological Activity Test

Biological activity tests were done by Applied Microbiology Department Ebonyi State University Abakaliki. Four human pathogens; *Escherichia coli*, *Pseudomonas aeruginosa, Streptococcus pnemoniae* and *Staphylococcus aureus* were used for the susceptibility tests.

i. *Broth Dilution Assay*

Ten sterile capped tubes were used; 2.0 mL of 100 mg/mL of the plant solution was introduced into the first test tube. About 1.0 mL of sterile broth was added to all the test tubes. One mL (1.0) was transferred to the second test tube, the content was mixed and 1.0 mL of it transferred to the third test tube. The process was repeated till the eighth tube, the ninth tube was used as the control.

A suspension of the microorganisms *Escherichia coli*, *Pseudomonas aeruginosa, Streptococcus pnemoniae* and *Staphylococcus aureus* were made to appropriate turbidity in 5.0 mL of Mueller-Hinton broth to give a slight turbid suspension. This suspension was diluted aseptically by introducing 0.2 mL of the suspension into 40 mL of Mueller-Hinton broth. One (1.0) mL of the diluted suspension was added to each of the test tubes and incubated at 35^0C overnight. Signs of visible microbial growth were examined (Woods and Washington, 1999; Nwokonkwo, 2010).

ii. *Agar Well Diffusion Assay*

A suspension of *Escherichia coli, Pseudomonas aeruginosa, Streptococcus pnemoniae* and *Staphylococcus aureus* were made in Mueller-Hinton broth at an appropriate turbidity. A sterile cotton swab was streaked over Mueller-Hinton broth using swab sticks. A cork borer was used to bore 7 cm hole on the inoculated media using sterile hole-borer. The plant extract was prepared in different concentrations of 100 mg/ mL, 50 mg/ mL, 25 mg/ mL, 12.5 mg/ mL and 6.25 mg/ mL.

1 mL of each concentration of the plant extract was inoculated into each borer, and the plates incubated at 35^0C for 24 h; after which the diameter of the zone of growth inhibition around each hole was measured to the nearest mm.

III. RESULTS

The stem bark extract of *Theobroma cacao* showed the presence of plant chemical indicated inTable 1. The minimum inhibitory concentration (MIC) and the inhibition zone diameter (IZD) results are shown in Tables 2 and 3.

Table 1 : Result of the Phytochemical Screening of the Stem Bark Extract of *Theobroma cacao*

Phytochemical	Result
Alkaloid	+++
Tannin	++
Saponin	+++
Glycoside	+
Phenol	+++
Flavonoid	+
Carboxylic acid	+

+++ *Significant presence, ++ appreciable present, + moderate presence*

Table 2 : Minimum Inhibitory Concentration of the Stem Bark Extract of *Theobroma cacao*

Clinical Organism	Concentration (M)	Activity
Escherichia coli	1×10^{-8}	+
	1×10^{-7}	+
	1×10^{-6}	+
	1×10^{-5}	+
	1×10^{-4}	+
	1×10^{-3}	+
	1×10^{-2}	+
	1×10^{-1}	+
Pseudomonas aeruginosa	1×10^{-8}	+

	1×10^{-7}	+
	1×10^{-6}	+
	1×10^{-5}	+
	1×10^{-4}	+
	1×10^{-3}	+
	1×10^{-2}	+
	1×10^{-1}	+
Streptococcus pnemoniae	1×10^{-8}	-
	1×10^{-7}	-
	1×10^{-6}	-
	1×10^{-5}	+
	1×10^{-4}	+
	1×10^{-3}	+
	1×10^{-2}	+
	1×10^{-1}	+
Staphylococcus aureus	1×10^{-8}	-
	1×10^{-7}	-
	1×10^{-6}	+
	1×10^{-5}	+
	1×10^{-4}	+
	1×10^{-3}	+
	1×10^{-2}	+
	1×10^{-1}	+

+ effective, - ineffective

Table 3 : Inhibition zone Diameter (IZD) mm of the Stem Bark Extract of *Theobroma cacao*

Test organism	Inhibition zone diameter(mm) Concentration (mg/mL)				
	100	50	25	12.5	6.25
Escherichia coli	30±1	28±1	25±2	23±1	-
Pseudomonas aeruginosa	30±2	25±1	23±1	22±1	-
Streptococcus pnemoniae	31±1	27±2	24±2	22±2	-
Staphylococcus aureus	27±1	24±2	20±2	22±2	-

-No activity, 20- 25 Appreciable activity, > 25 High activity

IV. Discussions

Table 1 showed the presence of seven different phytochemicals; alkaloid, saponin and phenol were present in significant amount; tannin was also present in substantial amount while glycoside, flavonoid and carboxylic acid were also indicated. Alkaloids have biological activity and are often the active constituents of various medicinal plants (Manske, 2007; Pelletier, 2001) and comprise the largest family of natural organic products. Saponins are able to destroy cell membranes of micro organisms and show heamolytic, spermicidal and cytotoxic activity. Phenols are natural products that have strong antibacterial and antifungal effects, flavonoids are compounds that offer disease and bacterial defense. Glycoside and flavonoid have also been discovered to exhibit biological and physiological effects. The plant sample showed Minimum Inhibitory Concentration (MIC) at a concentration of 1×10^{-8} M for *Escherichia coli* and *Pseudomonas aeruginosa,* while the MIC for *Streptococcus pnemoniae* was at a concentration of 1×10^{-5} M and 1×10^{-6} M concentration for *Staphylococcus aureus*. That is to say that even at the highest dilution of 1×10^{-8} the plant sample was still

active against two of microorganisms; *the Escherichia coli* and *Pseudomonas aeruginosa.* The inhibition zone diameters (IZD) for the organisms at a concentration of 100 mg/mL were 30±1, 30±2, 31±1 and 27±1; at a concentration of 50 mg/mL, the IZD values were 28±1, 25±1, 27±2 and 24±2; at 25 mg/mL, 25±2, 23±1, 24±2 and 20±2 while at 12.5 mg/mL, the IZD values were 23±1, 22±1, 22±2 and 22±2 for *Escherichia coli*, *Pseudomonas aeruginosa, Streptococcus pnemoniae and Staphylococcus aureus* respectively. At a concentration of 6.25 mg/mL the growth of *Escherichia coli*, *Pseudomonas aeruginosa, Streptococcus pnemoniae and Staphylococcus aureus* were not inhibited. Since the IZD values of the plant extract at 12.5 mg/mL were appreciable, the implication was that this plant extract could serve as a source for the treatment/cure for some bacterial infections especially those posed by the four pathogens investigated. The use of ethanol as a choice solvent was because an infusion or decoction of a glass of the stem bark of *Threobroma cacao* could be made with vodka, brandy or even champagne on "rocks" and taken. The IZD values were high values when compared to the fact that at IZD of 15-20 mm the growth of a microorganism could be inhibited. *Theobroma cacao* is a very useful plant in that while the fruiting body of *Theobroma cacao* produces an antioxidant the stem bark is a good antimicrobial agent: hence this plant part may be looked at as a potential source of antimicrobials.

The quest for natural products from plants having significant physiological properties is growing everyday and cuts across the globe; plants' extracts can be given singly or as concoctions for various ailments. People are relying on herbs to meet their various health needs; these are safe, may be consumed with little or no side effect, easily accessible and cheap.

With the improvement of process formulation and production technology, various formulation can be made available using plant extracts in form of tablets, capsules, granules, oral liquid, injections which can be used to treat bacterial infections, cardio-cerebrovascular diseases, liver, kidney, lung disorders with satisfactory effects (Guo et al., 2001; Xueli et al., 2001).

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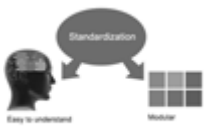
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3. Submission of Manuscripts,

4. Manuscript's Category,

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12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript-- must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including <u>definite statistics</u> - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.

- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

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- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.

- Do not give permission to anyone else to "PROOFREAD" your manuscript.

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- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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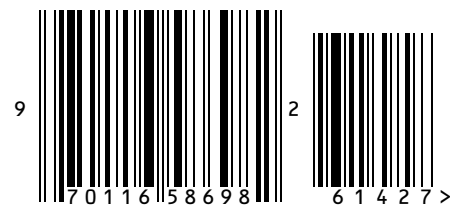| Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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