**Malaysian Journal of Fundamental & Applied Sciences**

**available online at** http://mjfas.ibnusina.utm.my

# Comparison QA methods of brachytherapy using well ionization chamber and in-air method

Nor Faranaz Shamin Nor Azmi[1,*], Ahmad Zakaria[2], Reduan Abdullah[2] and Norha Abdul Hadi[1]

[1] *Department of Applied Sciences, Universiti Teknologi MARA Pulau Pinang, 13500 Pulau Pinang, Malaysia*
[2] *School of Health Sciences, Health Campus, Universiti Sains Malaysia, 16150, Kubang Kerian, Kelantan, Malaysia,*

Received 19 December 2011, Revised 5 July 2012, Accepted 15 July 2012, Available online 22 August 2012

**ABSTRACT**

The aim of this project is to do comparative study in calibrating Ir-192 source using well ionization chamber and air measurement using Farmer ionization chamber**.** To calibrate the Ir-192 using well ionization chamber, the HDR unit was programmed so that the source was at the most sensitive position inside the well-chamber. The charges were measured at 45 second time interval two times using the electrometer operated at +300V and -300V. Sources air kerma strength was determined based on the AAPM task group 43 brachytherapy dosimetry protocol. In the in-air method using the Farmer ionization chamber and calibration jig, the HDR unit was programmed so that the source was at the position that gave the maximum response in the catheter. The source air kerma strength was calculated using a formula proposed by Goestch *et al*, (1991). The Ir-192 source air kerma strength by the well chamber was 2.7780cGym$^2$/h while in the in-air measurement was 2.609cGym$^2$/h. Both results are less than 3% from the source strength written in the calibration certificate. The well chamber method is quite direct and less time consuming compare to the in-air measurement and this is the method utilised in HUSM.

| Quality assurance | HDR Brachytherapy | Well ionization chamber | In-air Method | Ir-192 |

® 2012 Ibnu Sina Insitute. All rights reserved.
http://dx.doi.org/10.11113/mjfas.v8n4.152

## 1. INTRODUCTION

Brachy is from a G reek word for "short", so brachytherapy means short distance therapy. [1] In clinical work, brachytherapy is the used of sealed radioactive sources which is places close proximity to the treatment target volume. $^{192}$Ir is commonly radioactive sources for high dose rate brachytherapy. This is because $^{192}$Ir is an economical and safe especially when the patient load is high. Moreover, $^{192}$Ir has a short half-life that compels the user to change the source at every interval of four to five months [2].

Frequent calibration of source at the time of source exchange and routine quality assurance of brachytherapy unit require a use of established and recommended calibration procedure [3]. There are two recommended methods for the calibration of $^{192}$Ir sources, first by using re-entrant well-type ionization chamber and second by in-air (or Jig phantom) measurement using a Farmer-type ion chamber.

The calibration of brachytherapy sources is dependent largely on the source strength. The strength of a brachytherapy source may be specified in terms of activity, exposure rate at a s pecified distance, equivalent mass of radium, apparent activity, or air kerma strength.

The American Association of Physicist in Medicine (AAPM) recommends air kerma strength , $S_k$ is specified as tern for brachytherapy source strength [4].

In practice, $S_k$ is determined from exposure rate **(**X**)** measured in free air at a distance of 1 m from the source. There are generally three different methods of measuring the air kerma rate based source strength: (1) Measurement of air kerma rate in an in air set-up using an adequately calibrated ionization chamber and the extraction of the source strength;(2) Measurement using an in reference air kerma rate KR or equivalently air kerma strength $S_K$ calibrated well-defined chamber; and (3) Measurement using a solid phantom of well-defined geometry which is supplied with correction factors for extracting the source strength from the measured charge or current by using an ionization chamber.

In in-air calibrations, the measured charge or current is strongly dependent on the measurement distance and errors in the distance may lead large uncertainties in the source calibration. [5]

To improve accuracy, several distances should be used for calibration using in-air measurement. Even though well type chamber provide an easy, fast and reliable method for source calibration, it must be set in mind that in-air calibration is a more fundamental method.

*Corresponding author at:
*E-mail addresses:faranaz@ppinang.uitm.edu.my (Nor Faranaz)*

## 2. EXPERIMENTAL

### 2.1 The Well-Type Ionization Chamber Method.

When the electrometer was turned on, the battery status was checked to make sure power was adequate. The Zero Adjust Procedure was performed to attain 0.00nA so that there are no counts registered. The Mode Selector Switch was set to ZERO when the zero bar was displayed on the LCD. The Zero Adjust Knob was adjusted until the lit square on the bar stop moving and the ok message was displayed.

The well-chamber was placed in the same room as the HDR unit for at least 30 minutes before the measurement to allow it to equilibrate to ambient temperature and pressure. The well-chamber was use with the microSelectron HDR remote afterloading unit and connected to the Standard Imaging CDX-2000A electrometer outside the treatment room. The electrometer and HDR unit were warmed up for 10 minutes. The calibration of the measuring system was performed by the University of Wisconsin ADCL which supplied the 192Ir air kerma strength calibration factor for the instrument [6]

Well ionization chambers will respond to scatter radiation. Hence, when used, they should be placed well away from walls that may scatter radiation back to the chamber. They should be used in the same location, in a constant geometry, in a r eproducible manner. If moved from one location to another where the actual measurements are made, allow adequate time for the well chamber to reach equilibrium temperature with the air in the room[7].

By using an endobronchial catheter, the chamber was connected to one of the channel at HDR remote afterloading unit. The temperature and pressure inside the treatment room was measured and recorded. The temperature and pressure correction factor, $C_{T,\ P}$ was calculated using the equation below:[8]

$$C_{T,\ P} = \frac{273.15+T}{295.15+T_0}\ x\ \frac{760}{P}$$

Where T is the temperature in $^0$C and P is the pressure expressed in Torr (mmHg at $0^0$C).

When the system had warmed up, the back dot on the well insert was aligned to the punch mark on the body of the chamber. The catheter end was inserted to the centre of the chamber through the HDR Iridium source holder insert.

Normally, the most sensitive spot for the HDR 1000 plus chamber is between 50 and 53 mm from the bottom of the source tube (Standard Imaging HDR 1000 pl us ionization, 1997).

The HDR unit was programmed so that the source moved in 2.5 mm step from the top to the bottom of the chamber and the cable length was 995 mm. Charge in nanoCoulombs (nC) was collected twice at +300V for 30 seconds using an electrometer. The electrometer was switched to RESET mode after recording the charge reading; then switched to START mode when the source was at another position.

This was to make sure the charge was measured at the selected position. The position where most charge was collected is the most sensitive position of the chamber, then the most sensitive position verified.

After verifying the most sensitive position, the HDR unit was programmed so that the centre of the $^{192}$Ir source was at the position in the catheter corresponding to the most sensitive position of the chamber for 500 s econds. The charge was then measure at 45 seconds interval for twice times using the electrometer at +300 V,-300 V, +150 V and -150 V respectively. This is to obtain the correction for collection efficiency at the time of calibration.

$$\text{A ion} = \left\{\frac{\frac{M_1}{M_2}-1}{\frac{V_1}{V_2}-1}\right\}+1$$

The charge would only collected when the treatment LED stopped blinking in order to make sure the source was at the selected position. After waiting for 2 minutes, the voltage polarity was changed. This is to minimize the polarity effect and to let the electrometer stabilize. All the electrometer reading were recorded and converted to current.

$$\text{Current (I)} = \frac{\text{Charge (Coulomb)}}{\text{time (second)}}$$

The source air kerma strength was determined by using the AAPM Summer School 1994; brachytherapy physics

$$S_k = N_{sk} \text{ x } C_{T,\ P} \text{ x } A_{ion} \text{ x } A$$

Where:

| | |
|---|---|
| $S_k$ | is the air-kerma strength of the $^{192}$Ir source |
| $N_{sk}$ | is the air kerma strength calibration factor for the well type ionization in cGym$^2$/Ah |
| $C_{T,P}$ | is the correction for temperature and pressure |
| $A_{ion}$ | is the correction for collection efficiency at the time of calibration. |
| A | is the current measured from the well chamber. |

### 2.2 The in-air (jig) method.

The calibration jig was placed on an adjusted table. Following the suggestion of the AAPM Task Group No. 41, Source and chamber should be near the center of a l arge room and well above the floor, to minimize any contribution from room scattering. So, the apparatus was placed more than 1 meter from the floor and ceiling. When the electrometer was turned on, the battery status was checked to make sure power was adequate.

The electrometer and HDR unit were warmed up for 10 minutes. After 10 minutes, the Mode Selector Switch at the electrometer was set to the CHARGE position. The

temperature and pressure inside the treatment room was measured and recorded.

The temperature and pressure correction factor, $C_{T,P}$ was calculated using the equation below:

$$C_{T,P} = \frac{273.15+T}{295.15+T_0} \; x \; \frac{760}{P}$$

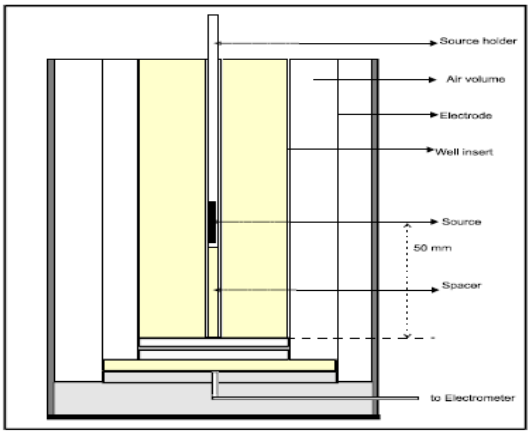


**Fig. 1** Positioning of the source and spacer in the well-type ionization chamber. (from IAEA TECDOC-1972,2002)

### 2.3 The in-air (jig) method.

The calibration jig was placed on an adjusted table. Following the suggestion of the AAPM Task Group No. 41, Source and chamber should be near the center of a l arge room and well above the floor, to minimize any contribution from room scattering. So, the apparatus was placed more than 1 meter from the floor and ceiling. When the electrometer was turned on, the battery status was checked to make sure power was adequate.

The electrometer and HDR unit were warmed up for 10 minutes. After 10 minutes, the Mode Selector Switch at the electrometer was set to the CHARGE position. The temperature and pressure inside the treatment room was measured and recorded.

The temperature and pressure correction factor, $C_{T,P}$ was calculated using the equation below:

$$C_{T,P} = \frac{273.15+T}{295.15+T_0} \; x \; \frac{760}{P}$$

The farmer chamber without build cap was placed in the jig chamber holder and connected to the Victoreen electrometer model Max-4000 outside the treatment room. Source to chamber distance used was 10 cm. By using a connecting tube, the catheter fixed at the jig was connected to one of the HDR unit's channel. A Nucletron source position simulator was used to measure the treatment length at a point parallel to the chamber effective point which was 991mm. To make sure the source was at the 991 mm treatment length, a 1cm x 3 cm Gafchromic film was attached at the above point on the catheter. The HDR operation console unit outside treatment room was programmer to move the sources in 2.5mm stepsize.

**Fig. 2** The connecting tube from remote after loading was connected to the fix catheter at the jig phantom.

After that, the HDR unit was programmed again so thet the source moved 2.5 mm step size from position 18 to position 22; each position time was 610 seconds. . Charge in nanoCoulombs (nC) was collected twice at +300V for 30 seconds using an electrometer. The electrometer was switched to RESET mode after recording the charge reading; then switched to START mode when the source was at another position. This was to make sure the charge was measured at the selected position.

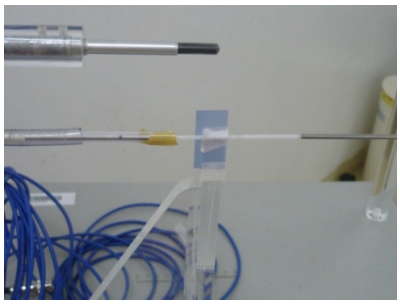

**Fig. 3** To verify the treatment length using Gafchromic film.

The position where most charge was collected is the most sensitive position of the chamber, then the most sensitive position verified **(see Table 3.0 and Table 4.0).** The charge was collected two times using the electrometer at +300 V,-300 V, +150 V and -150 V respectively. This is to obtain the correction for collection efficiency at the time of calibration.

$$A_{ion} = \left\{ \frac{\frac{M_1}{M_2} - 1}{\frac{V_1}{V_2} - 1} \right\} + 1$$

Once the $C_{T,P,}$ the position of maximum response and $A_{ion}$ had been determined, the HDR unit was programmed so that the source moved 2.5 mm step, position number 21 a nd treatment length 994 mm. Two charged

were collected at +300 V for 600 seconds each and recorded.

The $^{192}$Ir calibration factor, $N_{k,\,Ir}$ was determined by interpolation between chamber calibration factors for 250 kV x-rays with a half value layer (HVL) of 2.5 mm Cu and the $N_k$ for $^{60}$Co gamma rays.[9]

$$N_{k,\,Ir} = \frac{[0.8(A_{w,250kV}N_{k,250kV}) + 0.2(A_{w,Co}N_{k,Co})]}{A_{w,Ir}}$$

The source air kerma strength was determined by using Goetsch *et al*. Formula, [10]

$$K\,(d) = \left(\frac{Q-Q_L}{t}\right) C_{T,P} N_k P_{ion} A_{ion} P_{grad} \left(\frac{3600s}{h}\right)$$

Where,

K (d) is the air-kerma rate in free space and has units of Gy/h at the distance, d of measurement.
Q is the charge collected in the time t
$Q_L$ is the leakage charge collected in the time t
$P_{ion}$ is the correction for collection efficiency
$C_{T,\,P}$ is the correction for temperature and pressure
$N_K$ is the air-kerma calibration factor
$A_{ion}$ is the correction for the collection efficiency at the time of calibration
$P_{grad}$ is the gradient, or Kondo-Randolph, correction, and
3600 is the conversion from second to hours.

## 3. RESULTS & DISCUSSION

### 3.1 Calibration of Ir-192 using well type ionization and in-air measurement using Farmer type ionization chamber.

In this work, it's was started with verify the most sensitive position for both method. The most sensitive position is determined by measuring the most charge collected at each position.

**Table 1** Charges collected corresponding to well-chamber positions.

| Position | Charge(nC) |
|---|---|
| 18 | 1544.48 |
| 19 | 1734.21 |
| 20 | 1734.28 |
| 21 | 1732.24 |
| 22 | 1789.61 |
| 23 | 1874.94 |

**Table 2** Charges collected corresponding to vary position using +300 V polarities to in- air method.

| Position | Charge collected (nC) |
|---|---|
| 18 | -0.23 |
| 19 | -0.24 |
| 20 | -0.24 |
| 21 | -0.25 |
| 22 | -0.23 |

Table 1.0 shown that the sensitive position for well-type is at position 23 (This position obtain from the highest value of charge collected) while by refer the Table .2.0, the sensitive position for in-air method is position 21. Both are used the stepsize 2.5mm that being control by the control panel of remote afterloading.

**Table 3** Charges (nC) measured at +300 V, -300 V, +150 V and -150 V for well type chamber.

| Reading (nC) | Well-type ionization chamber. | | | |
|---|---|---|---|---|
| | 100% | | 50% | |
| | 300 | -300 | 150 | -150 |
| 1 | -2677.1 | 2699.35 | -2672.3 | 2684.39 |
| 2 | -2676.8 | 2691.22 | -2672.4 | 2687.1 |
| Average | -2676.9 | 2695.29 | -2672.4 | 2685.75 |

After verify the most sensitive position, the charges collected at most sensitive position was measured using electrometer at +300 V and -300V, also +150 V and -150V respectively. This is shown in Table 3.0 and Table 4.0

**Table 4** Charges (nC) measured at +300 V, -300 V, +150 V and -150 V for in air (jig) method

| Reading (nC) | in-air (jig) method | | | |
|---|---|---|---|---|
| | 100% | | 50% | |
| | 300 | -300 | 150 | -150 |
| 1 | -5.14 | 4.74 | -5.15 | 4.76 |
| 2 | -5.14 | 4.74 | -5.16 | 4.75 |
| Average | -5.14 | 4.74 | -5.155 | 4.755 |

The data obtained was useful to calculate the $A_{ion;}$ one of the factor need to consider to obtain the air Kerma strength (using AAPM formula for well-type method and Goestch *et al* for in-air method). T his is because the recombination correction, $A_{ion}$ may be required if sources with high air kerma rate were used.

### 3.2 Air kerma strength calculation (well - type method).

From the report of calibration for HDR well-type ionization chamber, air kerma strength calibration factor, $N_{sk}$ = 4.632 x $10^7$cGym$^2$/Ah

- Air kerma Rate = 5 2.30mGym$^2$/h is measure at dated 1 December 2007 at 8.07 a.m.
- Exposure Time = 45 sec
- Room Temperature, T = 21$^0$C; $T_o$ = 20$^0$C
- Treatment Room Pressure = 761Torr

$$C_{T,P} = \frac{273.15+T}{295.15+T_0} \; x \; \frac{760}{P}$$

$$= \frac{273.15+21}{295.15+20} \; x \; \frac{760}{761}$$

= 1.0021

$$\text{Current (I)} = \frac{\text{Charge (Coulomb)}}{\text{time (second)}}$$

$$= \frac{(2676.93 \; x \; 10^{-6})+(2695.29x10^{-6})C}{45 \; s}$$

= 5.969 x $10^{-8}$ A

$$\text{A ion} = \left\{\frac{\frac{M_1}{M_2}-1}{\frac{V_1}{V_2}-1}\right\}+1$$

$$= \left\{\frac{\frac{2686.11}{2679.05}-1}{\frac{300}{150}-1}\right\}+1$$

= 1.00264

Air kerma strength, $S_k = N_{sk} \times C_{T,P} \times A_{ion} \times A$

= 4.632 x $10^7$cGym$^2$/Ah x 1.0021 x 1.00264 x 5.969 x $10^{-8}$ A

= 2.7780cGym$^2$/h

Thus, Air kerma strength for $^{192}$ Ir = 2.7780cGym$^2$/h
From date 1/12/2007 at 8.07a.m to 5/2/2008 at 3.15p.m
The total time, T = 66 day 7 hours and 8 min.

≈ 66.29 day

Half life for $^{192}$Ir, $T_{1/2}$ = 74.2 day

From equation, $A = \frac{A_0}{2^n}$

Where's $n = \frac{T}{T_{1/2}}$

$$= \frac{66.29}{74.2}$$

= 0.8934

$$A = \frac{A_0}{2^n}$$

$$A = \frac{5.23 \; cGy \; m^2/h}{2^{o.8934}}$$

= 2.8155cGym$^2$/h

Different percentage, % = $\left\{\frac{2.8155}{2.7780}-1\right\} x \; 100\%$

= 1.3499% (< 3%)

### 3.3 Air kerma rate calculation (in air method)

From manufacture;

- $N_{k,250kV}$ = 88.36, $N_{k,Co}$ = 81.55
- Aw.250kV = 1.000, Aw,Co = 0.992, Aw,Ir = 0.992

$$N_{k,Ir} = \frac{[0.8(A_{w,250kV}N_{k,250kV})+0.2(A_{w,Co}N_{k,Co})]}{A_{w,Ir}}$$

$$= \frac{[0.8(1.00x88.36)+0.2(0.992 \; x \; 81.55)]}{0.992}$$

$$= \frac{86.86752}{0.992}$$

= 87.5681mGy/nC

= 8.7568cGy/nC

$$\text{Aion} = \left\{\frac{\left(\frac{m_1}{m_2}\right)-1}{\left(\frac{V_1}{V_2}\right)-1}\right\}+1$$

$$= \left\{\frac{\left(\frac{5.14}{5.155}\right)-1}{\left(\frac{300}{150}\right)-1}\right\}+1$$

= 0.9971

Room temperature; $T_0$ = 20$^0$C , after exposure T = 21$^0$C, Pressure, P = 761 Torr

$$C_{T,P} = \frac{273.15+T}{295.15+T_0} \; x \; \frac{760}{P}$$

$$= \frac{273.15+21}{295.15+20} \; x \; \frac{760}{761}$$

= 1.0021

The reference air kerma rate, K(d) =

$$\left(\frac{Q-Q_L}{t}\right) C_{T,P} N_k A_{ion} P_{grad} \left(\frac{3600s}{h}\right)$$

$$= \frac{\left(\frac{5.14nC-0.20nC}{600 \; s}\right)1.0021x0.9971x8.7568 \; cGy}{nC} x1.006 \frac{x3600 \; s}{h}$$

= 260.898cGy/h at 10cm

= 2.609Gym$^2$/h

Air kerma Rate = 52.30mGym$^2$/h at dated 1 December 2007 at 8.07a.m. This calibration had been done in 10 February 2008 at 11.17 a.m. From date 1/12/2007 at 8.07a.m to 10/2/2008 at 11.17a.m
The total time, T = 70 day 9 hours.

≈ 71 day

Half life for $^{192}$Ir, $T_{1/2}$ = 74.2 day

From equation, $A = \frac{A_0}{2^n}$

Where's $n = \frac{T}{T_{1/2}}$

$= \frac{71}{74.2}$

$= 0.9595$

$A = \frac{A_0}{2^n}$

$A = \frac{5.23\ cGy\ m^2/h}{2^{o}.9595}$

$= 2.6895 cGym^2/h$

Different percentage, % = $\left\{\frac{2.609}{2.6895} - 1\right\} x\ 100\%$

$= 2.974\%$ (< 3%)

After that, two methods were used to calibrate the $^{192}Ir$ source and the results were compared. The comparison was made by referring Table 5.0 and Table 6.0 and the results shown that the source air kerma strength using well-chamber calibration is $2.7780 cGym^2/h$ while the in-air measurement is $2.611 cGym^2/h$.

**Table 5** The air Kerma strength for Well-type ionization chamber.

| air Kerma strength, Sk ($cGym^2/h$ ) | | |
|---|---|---|
| Calculated | Calibration certificate | Percentage different, % |
| 5/2/08 at 3.15p.m Sk = 2.7780 | 1/12/07 - 5/2/08 Sk = 2.8155 | 1.3499 |

**Table 6** The air Kerma strength for In-air (jig) method.

| air Kerma strength, Sk ($cGym^2/h$ ) | | |
|---|---|---|
| Calculated | Calibration certificate | Percentage different, % |
| 10/02/2008 at 11.17a.m K(d) =2.611 | 1/12/07- 10/02/2008 K(d) = 2.6895 | 2.924 |

The AAPM task group recommend that the institution's verification of source strength can only disagree with the manufacturer to within ±10%[1]. When compared the in-air measurement air kerma strength with the value in the certificate, the results agreed to within 2.9%.

This mean both calibration results are acceptable for calibration the source. By referring the Table 4 and Table 5, it's shown that the percentage different of value calculated with the value from calibration certificate for in-air method is higher (2.9%) compared to well-type calibration (1.3%).

This is different from the theory that these two methods should have the same value of the air Kerma strength. This is because these two methods are done in two different days not in the same day. This may cause the half life of Ir-192 sources also different according to the day and the half life is the major factor to determine the source strength.

The well-chamber calibration method is easier, fast and straight forward compared to in-air measurement. The whole well-chamber calibration process only took about an hour to complete but in-air measurement required a few hours. This is due to the complexity of the in-air calibration protocol which requires several correction factors such as the temperature and pressure correction factor, $C_{T,P}$ the correction for collection efficiency at the time of calibration, $A_{ion}$ and the gradient or Kondo Randolph correction, $P_{grad.}$

Moreover, due to the low activity of the Iridium source used in this work, the in-air calibration took longer time than the expected time. Besides that, the in-air method required a lot of time because for measuring the charge or current in this method because it's strongly dependent on the measurement distance and errors in the distance may yield large uncertainties in the source calibration.

Moreover, to minimize the contribution of scattered radiation, the source and chamber should be placed in the centre of the room and well above the floor (at least 1 m from any wall or floor). Because considering all this factors, to complete this calibration using in-air method required a lot of time. This make the well-type method was chosen to utilised in HUSM.

Determining the air Kerma strength using in-air measurement for an HDR brachytherapy source requires attention to positional uncertainty and transit effect. By waiting until the current stabilized following a source or chamber movement before beginning the charge collection, transit effects are eliminated. Room scatter was ignored because Goestch *et al (1991)* had reported that room scatter air-kerma rate contribution does not change over a distance of 10 c m to 40 c m. Thus, in this work the correction for room scatter and transit effect was ignored.

## 4. CONCLUSION

The result of $^{192}Ir$ source air kerma strength by the well-chamber was $2.7780 cGym^2/h$ while the in-air measurement was $2.609 Gym^2/h$. As a conclusion, both results were within less than 3% with the source strength kerma from written in calibration certificate. The well-chamber calibration method is quite direct, reliable and less time consuming comparing to the in-air measurement. Thus, this method is recommended as a r outine method to calibrate HDR source for clinical used and utilized in Hospital Universiti Sains Malaysia (HUSM).

## ACKNOWLEDGEMENT

The authors thank the Radiotherapy Department HUSM, School of Health Sciences, Universiti Sains Malaysia and Department of Applied Science, Universiti Teknologi MARA Pulau Pinang for all the facilities, guidance and support.

## REFERENCES

[1] T.A Geisman, Organic Chemistry of Secondary Plant Metabolites, Freeman, Cooper and Company, California, 1969, 183-230.
[2] A. Mohamed Adib, F. Ahmad, and M. S. Idris, J. Chem. Sci., 120 (2008), 1-5.
[3] F. Neesa, Z, Ismail, N. Mohamed, and M. R. H. Haris, Food Chem., 88 (2004), 243-252.
[4] Z. Gao, K. Huang, X. Yang, and H. Xu, Biochim. Biophy. Acta., 1472 (1999), 643-650.
[5] J. A. Manthey, K. Grohman, and N. Guthrie, Curr. Med. Chem., 8 (2001), 135-153.
[6] K. Minato, Y. Miyake, S. Fukumoto, K. Yamamoto, Y. Kato, Y. Shimomura, and T. Osawa, Life Science, 72 (2003), 1609-1616.
[7] R, Jain, S. Nagpal, J. Shweta, and S. C. Jain, J. Medicinal and Aromatic Plant Species, 26 (2004), 48-50.
[8] M. Hu, K. Kransz, J. Chen, G. X. Jun, J. Li, and H. Gelboin, Drug Metabolism and Disposition, 31 (2003), 924-931.
[9] Y. Xia, Z. Y. Yang, P. Xia, K. F. Bastow, Y. Nakanishi, and K. H. Lee, Bioorg. Med. Chem. Lett, 10 (2000), 699-701.
[10] Ohtani, N. Gotoh, J. Tanaka, T. Higa, M. A. Gyamfi, and Y. Aniya, J. Nat. Prod, 63 (2000), 676-679.
[11] S. M. Kuo, Cancer Lett, 110 (1996), 41-48.
[12] K. R. Markham, Techniques of Flavonoids Identification, Academic Press, London, 1982,
[13] C. Selenski, and T. R. R. Pettus, Tetrahedron, 62 (2006), 5298-5307.
[14] G. Cao, E. Sofic, and R. L. Prior, Free Radic, Biol. Med, 22 (1997), 749-760.