# Multipoint-Plane Corona Discharge Configuration in Air Analysis and Its Possibility for Accelerating the Growth of Rice

Sumariyah[a,b], Alfatihatuz Zulfah Zain[a], Avrilina Rahmawati[a], Zaenul Muhlisin[a,b], Fajar Arianto[a,b],
[a]Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Semarang 50275, Indonesia
[b]Center for Plasma Research, Faculty of Science and Mathematics, Diponegoro University, Semarang 50275, Indonesia

Eko Yulianto[b], Andi Wibowo Kinandana[b] Hery Sugiartono[c],and Muhammad Nur[a,b*]
[c]Mlatiharjo Farmer Community, Jalan Kromoyudha,Gajah,
Demak Regency 59581 Central Java, Indonesia

**Abstract:- The corona discharge with a multi-point-to-plane configuration has been analyzed, especially on its electrical characteristics. The electrical analysis of this type of plasma reactor is macroscopically similar to the I-V characteristics. By using the I-V. characteristics and the formulation which has been modified to include a factor of the number of point electrodes, the mobility of the charge carriers has been determined. The mobility that has been determined is the mobility of positive nitrogen ions according to the type of positive corona discharge. At the cathode in the form of a copper plate, a sample of rice is placed so that the sample is subjected to irradiation, the treatment of plasma species can cause accelerated rice growth. Ion mobility is carried out under atmospheric conditions with variations in the distance between the electrodes and. I-V characteristics are different because of the different distances so that the mobility is also different. The value of mobility obtained with the sample between the electrodes is always higher than without the sample rising. Ion irradiation was carried out by corona discharge with a high voltage (HV) at 4 kV DC and a current of 150 A at a distance of d = 2 cm. The rice has been irradiated were a premium types from Demak Regency, Central Java Indonesia. The results showed that plasma radiation can increase the growth of premium rice which includes the percentage of germination speed, root length, stem length, and rice mass. The optimum irradiation time for the growth of premium types of rise observed for 15 days was 30 minutes. The results showed that the total nitrogen content increased proportionally with the length of irradiation time. The high nitrogen content in rice seeds can be caused by the infiltration of positive nitrogen ions. It is suspected that nitrogen ions are deposited into rice so that rice has an optimum nitrogen content which can accelerate growth.**

***Keywords:-*** *Plasma Corona; Electric Field in Multi Point to Plane; Plasma Generation, accelerate growth of rice.*

## I. INTRODUCTION

The use of cold plasma for agriculture has begun to develop, for example for soybeans [1-2]. This development is also supported by its impact on seed cultivars and important crops, such as wheat [3]. The effect of cold plasma treatment on the morphology, genetics and physiology of plant seeds has been thoroughly reviewed [4]. One of the types of cold plasma is corona discharge. Corona discharge theoretically and experimentally has been reported by many authors. Research on characteristics of various electrode arrangements, which is typically point-to-plane for positive and negative corona [5,6,7,8,9,10]. The mobility of charge carrier in corona discharge also is attractive research, and it corresponds to the application in some areas such as drying, implantation, plasma agriculture, plasma environment [10,11,12,13]. Determination of charge carrier mobility, for corona discharge usually by using hyperboloid model [5], in general, approach geometry [14] and unipolar saturation current [16], as well as a distribution of field[16].

Germination, growth, yield and quality of crops is determined by the material properties of seeds, which can be enhanced by pre-sowing treatment, electric field, magnetic field, laser and microwave. Various surveys show that the development of living organisms is largely determined by the impact of different physical factors, such as the magnetic field. Various authors have found that the influence of a stationary magnetic field on the seed can lead their faster growth, activation of protein formation, and root growth [17]. Research on incandescent corona discharge plasma has been widely applied and developed , including to accelerate growth. Corona glow discharge plasma has been used to accelerate the growth of soybean black seed plants. This system consists a corona reactor with the configuration of electrodes of multi-points to plane [14]. Research on rising correspond to germination has been done for example an improved process for high nutrition of germinated brown rice production [18], changes in the chemical and functional components of Korean rough rice before and after germination [19]

This paper reports the analysis of corona discharge plasma electrically macroscopic and microscopic and its application potential to agriculture especially acceleration of growth premium rice in Indonesia.

In this paper the characterization of corona discharge plasma, determination of charge carrier mobilities will be presented. Corona positive plasma can produce nitrogen ions and its can be used for accelerate growth of germination of rice also will be discussed.

## II. METHODS

### *A. Experimental Set Up*

Figure 1 shows the experimental set-up of this study. Corona plasma reactor has a multi-point to a plane configuration. Point made of a needle stainless steel with a diameter of 20 µm amounts to 64 pieces. An electrode flat (plane) made of stainless steel circular with a diameter of 25 cm. Plasma generated by high voltage DC with max 10 kV. HV DC was measured by using an Oscilloscope after passing high voltage probe, HV Probe (max DC Voltage DC 40 kV, 28 kV AC EC code number 1010, EnG1010, Made in Taiwan). Electrical signals from the probe detected by an Oscilloscope GOS-653, 50 MHz.

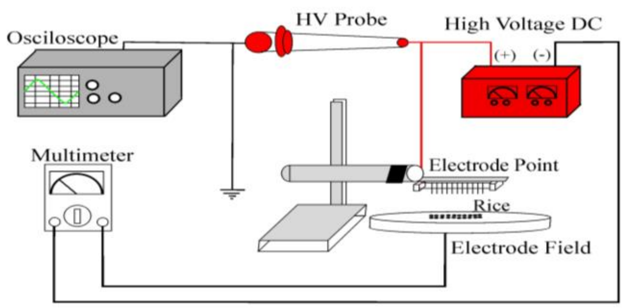



Fig.1. Experimental Set Up

The electric current, that was generated in the reactor was measured by using a multimeter (Sunwa TRXn 360) and ammeters (Kyoritsu, AC / DC Digital Clamp meter). The samples used for this study is a premium seeds of rice. Microwave Cosmos EN has been used for drying rice seeds before being fed into the treatment room. The stand and fixed were used to put and fixed the electrodes. For measurement the length of the stems of premium rice, a ruler has been provided. Balance ACS AD300i 300 grams capacity x 0.01 grams used to measure the mass of rice.

### *B. I-V Characteristics and Charge Carrier Mobility*

The determination of the value of average charge carrier mobility can be made based on current characteristics as a function of voltage using equation Sigmond[15]. The value of this unipolar ion mobility can be calculated using equation (1). But for the case of the multi-point electrode, this equation can be necessary modified a factor of the number of electrode points, which is considered N. In addition, the dielectric constant values also should be corrected. We have to use constant of dielectric samples between two electrodes, these samples can be considered as a dielectric material. Thus, the above equation becomes:

$$I_s = \frac{2\mu\varepsilon_t N}{d}(V^2) \tag{1}$$

From equation 1, a linear curve $\sqrt{I_s}$ as a function of V can be made, in order to obtain the gradient of the curve linearity. From the gradient value may be determined and average mobility of the charge carriers in the corona discharge. The effective of dielectric constant between two electrodes should be calculated. These materials include air and rice as a sample.

## III. RESULTS AND DISCUSSION

### *A. I-V Characteristics*

The air is the dielectric can function as a barrier, if these obstacles are reduced, in this case, the reduction of the distance between the two electrodes by the addition of the sample, then the electric current will be greater at a voltage with the same value. The electric current as a function of voltage with and without the sample shown in Figure 2, below.

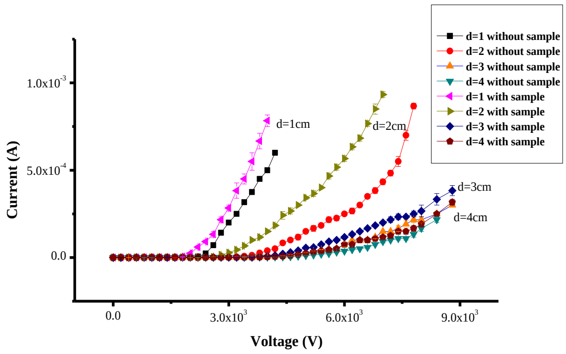



Fig. 2: The characteristic of electric current as a function of voltage with and without sample

Figure 2 explains the presence of the sample that was placed on the plate electrode, for any distance, electric current is always high than electric current without the sample. This is because of the sample can affect a number of charges. There is polarisation inside the samples that causes the distance between the electrode point positively charged with electrode plane negatively charged become close. Distances are closer can reduce the resistance of air that separates the two electrodes. Therefore, electric current for discharge with a sample is higher than without the sample.

Figure 2 shows that both have the same characteristics, giving the rice sample did not alter the characteristics of current and voltage. Current value increases with augmenting of voltage. It can also be shown that the current as a function of voltage follow law quadratic corona discharge, with a current value proportional to the square of the voltage ($I \approx V^2$). It conformed to the predictions of Sigmond [15] that the characteristic of current versus voltage for corona discharge at atmospheric conditions following the second order polynomial equation. In this case, the air which initially serves as an insulator can function as a conductor cause of the influence very high of the electric field. The electrons accelerated by electric field and involved collisions with gas molecules. The electrons ionise the air which is located between the two electrodes, as the main constituent molecules of air are nitrogen ($N_2$) of (78.09%), the results of ionisation due to electron collides with a N+ ion. The influence of the electric field causes the N+ ions move toward the cathode through the watershed. The movement of these ions that cause ion currents in the ampere meter read, called the saturation current unipolar.

From the analysis of data obtained by the characterization of ion $N^+$ optimum electrode distance of 2 cm, at a voltage of 4 kV and a current of 150 µA. The results are then used as a reference for irradiation in rice seed samples to be tested the levels of total nitrogen. Selected to the electrode spacing of 2 cm because at a distance of less than 2 cm prone arise due to the current arc discharge and high electric field and at a distance of 3 cm and 4 cm larger voltage required to generate glow discharge plasma corona.

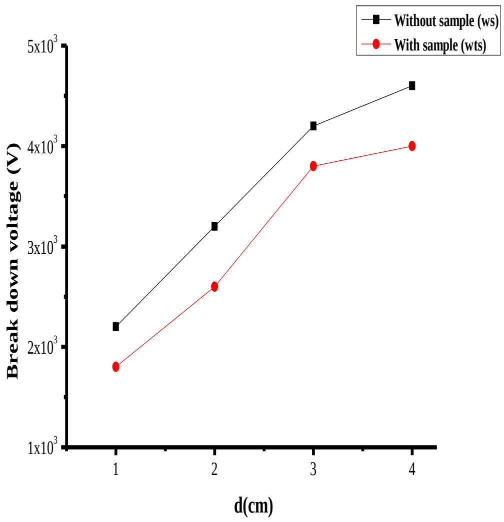



Fig. 3: The characteristic of breakdown voltage as a function of distance between electrodes

Free air that fills the space between the electrodes, initially the air is a dielectric material that has a current-carrying small, there are no electrons move freely because they bind tightly to the bottom line until at a certain voltage that could damage the dielectric properties of air and turn them into conductors referred to breakdown voltage. Breakdown voltage is affected by the distance between the electrodes, the greater the distance between the two electrodes, the breakdown voltage used for converting the higher the air becomes a conductor. Breakdown voltage value as a function of the distance can be seen in Figure 3.

In addition, Figure 4 also show that at a fixed voltage, saturation current unipolar will decrease with increasing distance between the two electrodes. When the distance between the two electrodes is enlarged, the electric field generated will be smaller. This is consistent with research conducted Bamji et al [16] on the relationship between the electric field at a distance of two electrodes. When an electric field is reduced, the ionisation process will also decrease around the anode which can reduce productivity and lead to positive ions reduced the flow of positive ions.

In addition, Figure 3 also show that at a fixed voltage, saturation current unipolar will decrease with increasing distance between the two electrodes. When the distance between the two electrodes is enlarged, the electric field generated will be smaller. This is consistent with research conducted Bamji et al [16] on the relationship between the electric field at a distance of two electrodes. When an electric field is reduced, the ionisation process will also decrease around the anode which can reduce productivity and lead to positive ions reduced the flow of positive ions.

*B. Average Charge Carrier Mobility*

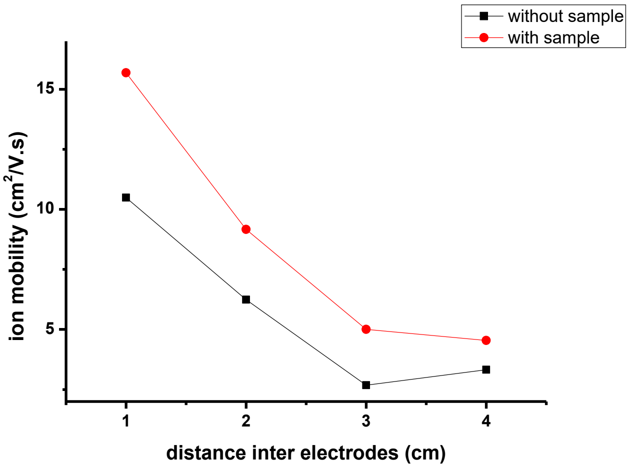



Fig.4 Ion mobility as a function of the distance between the electrodes

The effect of distance between two electrodes to the average charge carrier mobility value shown in figure 4. The value of mobility will decrease with increasing distance between electrodes. By increasing distance between electrode involves reduction the value of the electric field. While, it is known that the electric field pushes ions toward the cathode where rice seed placed. When electric field decrease, it is due to the flow of ions will be slower and flux of ions become smaller to the attract by the cathode. The flow of ions that the slower it will influent to unipolar current value. Moreover, by decreasing the value of the current unipolar lead to the difference of mobility.

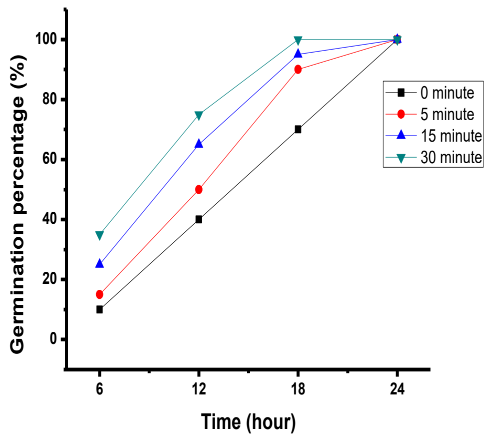
The results of the determination of the average of charge carrier mobility in this study are worth 2-16 $cm^2/V.s$. This results showed that the mobility values obtained from some variation of the distance "d", approaches the mobility of ions to the air of Langevin (as shown in Figure 4) that scored the mobility of about ± 2 $cm^2/V.s$ to atmospheric air pressure [10]. The difference between the value of mobility is obtained based on this study and the results Langevin is because in this study used multi-point and multiple variations of the distance between the electrodes, while Langevin uses a single point and the distance between the electrodes.

The difference value of mobility with the sample and without the sample due to the dielectric properties of the sample. Rice seed has a dielectric constant of ± 3. Large

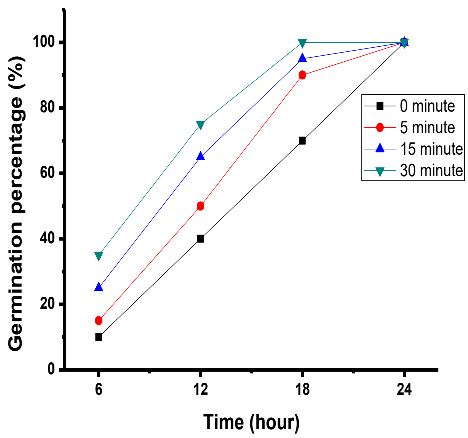
ISSN No:-2456-2165

dielectric constant value depending on the material's response to the external effects. According to the principle that occurs in a dielectric capacitor when added will increase the amount of charge that flows at the same voltage. When the amount of charge that flows more than the current value will be even greater. In the corona discharge with the sample, the increase in current value causes of the higher value of mobility with the sample.

### *C. Germination and Growth Accelerated*




(A)




(B)

Fig. 5: The germination percentage in rice sample of 'Ciherang' (A), and 'Sultan' (B) brands over the time. The germination process observed with variations of treatment time

Figure 5 shows the effect of irradiation to the germination percentage in rice sample of premium brand over the time. The germination process observed with variations of treatment time. It can be seen in Figure 5 for rice types premium and Figure 6 for rice types "Sultan". In premium rice premium types, the average number of rice which germinated in the first 6 hours is 1 seed (5%) for paddy radiation 0 minutes, 2 seed (10%) for radiation 5 minutes, 3 seed (15%) for radiation 15 minutes, and 5 seeds (25%) for 30 minutes of radiation. When 6 hours the second, 11 seed (55%) for paddy radiation 0 minutes, 13 (60%) of seeds to radiation 5 minutes, 15 seed (75%) for radiation 15 minutes, and 18 (90%) of seeds to radiation 30 minutes , Third at 6 hours, 18 seed (90%) for paddy radiation 0 minutes, 18 seed (90%) for radiation 5 minutes, 20 seeds (100%) for 15 minutes of radiation, and 20 radiation seeds for 30 minutes. All twenty samples germinated rice at 6 hours fourth.

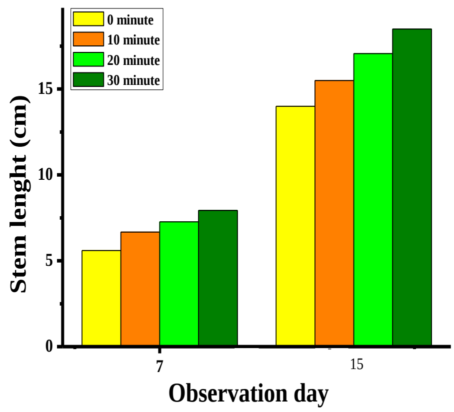



Fig. 6: The stem length of the sample as a function of irradiation time on the dayof 7th and day 15th

In premium rice types Sultan, the average number of rice which germinated in the first 6 hours is 2 seed (10%) for paddy radiation 0 minutes, 3 seed (15%) for radiation 5 minutes, 5 seed (25%) for radiation 15 minutes, and 7 seed (35%) for 30 minutes of radiation. When 6 hours the second, eighth seed (40%) for paddy radiation 0 minutes, 10 seed (50%) for radiation 5 minutes, 13 (65%) of seeds to radiation 15 minutes, and 15 seeds (75%) for radiation 30 minutes , When 6 hours of the third, 14 seed (70%) for paddy radiation 0 minutes, 18 seed (90%) for radiation 5 minutes, 19 seed (95%) for radiation 15 minutes, and 20 seeds (100%) for radiation 30 minutes , All twenty samples germinated rice at 6 hours fourth.

Based on figure 5 and figure 6 above shows that the faster germination in irradiated for 30 minutes is due to the longer time of irradiation in rice, then the nitrogen ions are deposited on rice will be more and more. Nitrogen serves to increase the vegetative growth of rice plants that germinate faster. We found that N2 inside the rise seed increases 0.2 % after an irradiation time of 30 minutes. Moreover, it can be concluded that the speed of growth or percent germination rate is proportional to the irradiation time. At germination which has reached 100% means that all the right rice irradiated at 5 minutes, 15 minutes, and 30 minutes have germinated after 24 hours as well as for rice nonirradiated.

At the time of analysis of irradiation on the speed of growth will be observed the length and color of the leaf stalks of rice on day 7 and day 15 after planting are presented in Figure 7. The conditions of Ciherang rice seeds irradiated by plasma corona generated at a voltage of 4 kV, current 150 uA spaced electrodes 2 cm. Planting of rice seeds is done after soaking in water for two days and two nights to increase the water content owned seed. Rice seed planted in polybags and watered every one day.

The subsequent observations of growth velocity were conducted on day 15th. The stem length of rice plants that have been irradiated plasma was observed. We found that stem duration of rising with time irradiated of 30 minutes could reach until 18.3 cm, while the length of the rice stem control only 14 cm. At the time of radiating 10 and 20 minutes long stalks of rice is 15.5 cm and 17 cm. From now on observations are concerning leaf color. The leaf color was more dark green with increasing the length of time the seed irradiation. In the rice seed that has been irradiated for 30 minutes seems very dark green color. For the rice control, the leaf color appears light green and slightly yellowish. Base on this results, it should be concluded that irradiation with positive corona plasma can accelerate the growth of rice and health in the next rice growth.

## IV. CONCLUSION

For all distance, breakdown voltage corona discharge with a sample is always less than the breakdown without a sample. The mobility of charge carrier in corona discharge with geometry multipoint-plane can be determined by using modified Sigmond formula. Mobilities with samples are high than mobilities without a sample in the plane electrode, and both mobilities decrease with increasing inter-electrodes distance The speed of growth or percent germination rate is proportional to the irradiation time. At germination which has reached 100% means that all the good rice irradiated at 5 minutes, 15 minutes, and 30 minutes have germinated after 24 hours as well as for rice non-irradiated. Irradiation with positive corona plasma can accelerate growth of rice and health in the next rice growth.

## ACKNOWLEDGMENT

Small part of financial support of this research (in kind equipment) suppoted by the PT. Dipo Technology and Mlatiharjo Farmer Community

## REFERENCES

[1.] Renáta Švubová, L'udmila Slováková, L'udmila Holubová, Dominika Rov ˇnanová, Eliška Gálová and Juliána Tomeková, Evaluation of the Impact of Cold Atmospheric Pressure Plasma on Soybean Seed Germination, Plants (2021), 10, 177.pp 1-17

[2.] Nelumbo Nucifera1 Muhammad Al Jabbar Kanie, Sulistiyani Hayu Pratiwi, Rulita Pratiwi, Sapto Purnomo Putro, Muhammad Nur, Corona Discharge Plasma Technology to Accelerate the Growth of Black Soybean Plants, Journal of Natural Sciences Research, 14 (2016) pp. 35-40

[3.] Pia Stariˇc, Silva Grobelnik Mlakar. and Ita Junkar, Response of Two Different Wheat Varieties to Glow and Afterglow Oxygen Plasma, Plants (2021), 10, 1728 pp. 1-12

[4.] Pia Stariˇc, Katarina Vogel-Mikuš, Miran Mozetiˇ and Ita Junkar, Effects of Nonthermal Plasma on Morphology, Genetics and Physiology of Seeds: A Review, Plants (2020), 9, 1736 pp. 1-18

[5.] R.. Coelho, J. Debeau, Properties of the tip-plane configuration, J. Phys. D: Appl. Phys., 4, (1971) pp. 1266

[6.] J.E. Jones, On corona-induced gas motion and heating I:Field equations, modelling and vortex formation, Journal of Electrostatics, 66 (2008) pp. 84–93

[7.] C. Park Kim, D.K.C. Noh, and J. Hwang, Velocity and energy conversion efficiency characteristics of ionic wind generator in a multistage configuration, Journal of Electrostatics 68, (2010) pp. 36–41

[8.] R. Morrow, Theory of negative corona in oxygen, Phys. Rev. A 32, (1985), pp. 1799–1809.

[9.] A.P. Napartovich, T.U.S.Akishev, A.A. Deryugin, I.V. Kochetov, M.V. Pan'kin, N.I. Trushkin, Numerical simulation of Trichel-pulse formation in a negative corona, J. Phys. D: Appl. Phys. 30 (1997) 2726–2736.

[10.] M. Nur, Etude des décharges couronne dans l'argon et l'azote trés purs: transport des charges, spectroscopie et influence de la densité, PhD. Thesis, Joseph Fourier University, Grenoble, France. (1997)

[11.] M. Nur, N. Bonifaci, and A. Denat, Non-thermal Electron Mobility in High density Gaseous Nitrogen and Argon in Divergent Electric Field, Vol. IV Proc. ICPIG XXIII, Toulouse, France (1997) pp. 12-13

[12.] M. Nur, N. Bonifaci, and A. Denat, Ionic Wind Phenomenon and Charge Carrier Mobility in Very High Density Argon Corona Discharge Plasma. Journal of Physics: Conference Series 495, 2014.

[13.] I.J. Timothy, P. Goodenough, W. Goodenough, and S. M. Goodenough, The efficiency of "corona wind" drying and its application to the food industry, Journal of Food Engineering, Volume 80, Issue 4, (2007) pp. 1233-1238

[14.] M. Robinson, Movement of air in the electric "wind" of the corona discharge, AIEE Trans. 80, (1961), pp. 143–150

[15.] [R.S. Sigmond, Simple approximate treatment of unipolar spacecharge-dominated coronas: the Warburg law and the saturation current, J. Appl. Phys. 53 (1982) 891–898.

[16.] S.S. Bamji , A.T. Bulinski , K.M. Prasad Electric field calculations with the boundary element method, IEEE Transactions on Electrical Insulation, Volume: 28 Issue: 3 pp. 420 – 424

[17.] Aladjadjian, The use of Physical Methods for Plant Growing Stimulation in Bulgaria. Journal of Central European Agricultures. 8 (3), (2007), pp. 369–380.

[18.] H. Chen, H. C. Chang, Y. K. Chen, C. L. Hung, S. Y. Lin, and Y. S. Chen, An improved process for high nutrition of germinated brown rice production: Low-pressure plasma. Food Chemistry 191 (2016) 120–12.

[19.] Y. R. Lee, J. Y. Kim, , K. S. Woo, I.G. Hwang, K. H. Kim, and J. H. Kim, Changes in the chemical and functional components of Korean Rough Rice before and after Germination. Food Science and Biotechnology. 16, (2007) 1006–1010.