Regression model of sunflower seed separation and the investigation of its germination in corona field

Seyyed Hossein Fattahi[1*], Shamsollah Abdollahpour[1], Hamidreza Ghassemzadeh[1], Hossein Behfar[1], Seyyed Abolghassem Mohammadi[2]

(1. *Department of Agricultural Machinery, University of Tabriz, 51368 Tabriz, Islamic Republic of Iran*;
2. *Department of Agronomy and Plant Breeding, University of Tabriz, 51368 Tabriz, Islamic Republic of Iran*)

Abstract: Seed separation and cleaning is one of the important processes in obtaining pure high quality seed. The main characteristics that influence the ability to separation seeds are seed size (length, width, and thickness), shape, density, surface texture, terminal velocity, resilience, color, and electrical conductivity. Electrostatic separation is based on differences in the ability of particles to develop and maintain electric charges. In this study, a high-tension roll-type electrostatic separator was constructed for the separation of sunflower's seed in order to extract pure seed and remove impurities. An extended corona discharge field was generated by three wire type electrodes in the roll-type separator. The experiment was performed in the form of factorial analysis based on a randomized complete block design with three replications. The mass of pure sunflower's seed was measured in the treatment combinations of the rotational speed (40, 50 and 60 rpm), electrode distance from roll (4, 5 and 6 cm) and the power supply voltage (20, 30 and 40 kV). The linear regression model was carried out for investigation of the impact of effective factors on sunflower separation. The result showed that rotational speed had the greatest impact on ideal separation. The germination experiment showed that the electric field of this separator had no significant effects on improving the germination of sunflower seed.

Keywords: sunflower seed germination, corona discharge, separation, regression model

Citation: Fattahi, S. H., S. Abdollahpour, H. Ghassemzadeh, H. Behfar, S. A. Mohammadi. 2017. Regression model of sunflower seed separation and the investigation of its germination in corona field. Agricultural Engineering International: CIGR Journal, 19(2): 187–192.

1 Introduction

Agriculture is the largest single industry in the world, and seed production is an important segment of this industry. Seed separation and cleaning is one of the important processes obtaining pure high quality seed. Attempts are being made to reduce seed losses by developing equipment and methods to improve efficiency in cleaning, treating, handling, and storing of seed (Harmond et al., 1968). Purity, germination and disease incidences determine seed quality. Seed cleaning and grading can achieve purity and separate small seeds. The separation can be carried out by the properties of physical, electrical, magnetic, optical, etc. Seed, as it comes from the field, contains various contaminants like weed seeds, other crop seeds, and inert materials such as stems, leaves, broken seed, and dirt. These contaminants must be removed. The clean seed which is properly handled and stored to provide a high quality planting seed will increase farm production (Harmond et al., 1968).

Electrostatic separation is based on differences in the ability of particles to develop and maintain electric charges. In a roll-type corona-electrostatic separator, the granular mixture to be separated is fed with a certain speed on the surface of a rotating roll electrode, connected to the ground. A high-intensity electric field is generated between this roll and one or several electrodes connected to a high-voltage supply (Dascalescu et al., 1998). The insulating particles are charged by ion

Received date: 2016-10-13 **Accepted date:** 2017-03-05

*** Corresponding Author**: **Seyyed Hossein Fattahi**, Department of Agricultural Machinery, University of Tabriz, 51368 Tabriz, Islamic Republic of Iran. Email: mir_fattahi@yahoo.com, Tel: +989141650331.

bombardment in the corona field zone and are pinned to the surface of the rotating roll electrode by the electric image force. Forces Acting on Insulating Particles (nonconductive particles) in Roll-Type Corona-Electrostatic Separators are the electric image force (F_i), centrifugal force (F_c) and the gravitational force (F_g). Particles detached from the rotating electrode (roll) when the resultant of gravitational and centrifugal forces surpasses the pinning action of the electric image force (Younes et al., 2013). The conducting particles are not affected by the corona field; they charge by electrostatic induction in contact with the grounded roll and are attracted to the high-voltage electrode (Dascalescu et al., 1995). Consequently, the list of factors influencing the electrostatic separation process should include the high-voltage level, the electrode configuration, the feed rate, the granule size, and the roll speed (Morar et al., 1993). Krishnan et al. (1985) made a belt-type electrostatic separator to remove flower parts from onion seeds. The best result was achieved at a voltage of 17 kV and by conveyor belt with a speed of 0.2 m s^{-1}. Leonov (1984) designed a rotary drum seed electrostatic separator using a PVC drum. The PVC drum rotated at 32 rpm and a voltage of 5 kV was applied.

Many studies have been carried out on the positive effects of high voltage of electric fields on yield and germination power of seed. High intensity fields with physiologic changes in seed that concluding in faster water absorption and respiration as well as intensifying of photosynthesis of germination result increase the biological capacities of seed. It has been believed that being exposed to biological process, including free radicals, activities stimulating proteins and enzymes increase seed power (Molamofrad et al., 2013). Grading seed by relying on mechanical properties used in conventional seed cleaner does not have a measurable effect on seed germination improvement (Konchenko and Trofimov, 2000). The most effective results were achieved when seed germination was stimulated by electromagnetic fields (Davies, 1996). Electromagnetic (electric and magnetic) fields cause physiological-biochemical changes in seeds. Water assimilation becomes faster and breathing and photosynthesis of germinating seeds intensifies. That results in improved viability of a viable seed (Putincev et al., 1997). Using magnetic fields activates enzyme complexes in the seed, which ensures faster growing of the germ, increases germination energy, and speeds up rooting (Carbonell et al., 2000). Many researchers studied the stimulation of seeds by using corona discharge electric field (Palov, 2003). Some of them suggested treatment with corona discharge field only (Palov, 2003; Borodin and Scerbakov, 1998), and noted an increase of viability within the range of 7%-19%. Corona discharge fields increase germination between 7% and 19% for carrot seeds (Lynikiene, 2001), between 18% and 26% for buckwheat seeds (Pozeliene et al., 2008), and 12% for barley (Lynikiene and Pozeliene, 2003).

In this study, effects of roll rotational speed, corona electrode distance from roll and DC power supply voltage (as effective factors in roll-type corona separator) with linear regression model on sunflower seed separation and electrostatic field effects on improving seed germination are investigated.

2 Material and method

A roll type corona electrostatic separator was constructed for separation of sunflower seeds (Figure 1). In this separator, to produce the corona field for sunflower charging three wire-type electrodes was used. Corona electrodes were connected a high voltage power supply with a maximum output voltage of 40 kV, direct current at 3 mA. Diameter of roll was 50 cm. The three corona electrodes were placed on roll with angle of 30, 50 and 70 degrees.

Figure 1 A laboratory roll-type corona separator

The sunflower mixture to be sorted are deposited by a vibratory feeder onto the surface of a grounded rotating roll electrode, which introduces them in a zone of intense electric field created by three high voltage electrodes. Three of the electrodes create a corona discharge, so that all the mixture of pure sunflower seeds (the sunflower seeds large in size are used for the next planting season in field) and MOG (MOG includes the medium and small sizes of sunflower seeds, leaves, broken and empty seeds, ray flowers and etc.,) are charged by ion bombardment. The mixture of sunflower and MOG adhered to the surface of the roll electrode under the effect of the electric image force. Then, sunflower and MOG will have the different detachment trajectory from the rotary roll. A nine-compartment bin was placed under the rotary roll into which the seeds fell from the roll. Finally, some of the charged seeds and MOG always adhered to roll and were removed by the brush. In this study, the hybrid variety of sunflower was used for the separation investigation. Mixture of sunflower and material other than grain were in the storage moisture of 9%-10%. 12 g of pure sunflower seed and 50 g of material other than grain were mixed with each other as the test samples. The sample weight in the first bin (the first bin on the right) under the rotary roll was investigated for the expression of sunflower separation. The weight of the pure sunflower seeds were recorded by using a digital balance (Model Adam, accuracy 0.01 g). The experiments at three rotational speed levels (40, 50, and 60 rpm), three electrode distance levels (4, 5 and 6 cm) and three power supply voltage (20, 30 and 40 kV) were conducted in the form of factorial analysis based on a randomized complete block design with three replications. SPSS-21 software was used to obtain the linear regression model.

To study the effects of the separator electrical field on sunflower seed germination, 30 intact and large seeds from the first bin (sunflower seeds achieved from the best treatment combination of separation) and unsorted (untreated) seeds were selected. The sunflower seeds planted in a pot filled with soil in the form of factorial analysis based on a completely randomized design with three replications separately. 12 days after planting, the percentages of germinated seeds were compared according to the following equation.

$$\text{Germination \%} = \frac{\text{Number of germinated seeds in each pot}}{\text{Number of total seeds in each pot}} \times 100$$

MSTAT-C software was used to investigation of sunflower germination in corona electric field.

3 Results and discussion

12 g pure sunflower seeds and 50 g MOG (the sum of the pure sunflower seeds and MOG were 62 g) are deposited to be separated by a vibratory feeder onto the surface of a grounded rotating roll electrode. The feed rate should be chosen such that the material could form a uniform monolayer on the surface of the roll electrode (Urs et al., 2004). The mixture is charged by ion bombardment with corona discharge of three wire-type electrodes. Then the mixture collected in bins under the rotary roll. The separation data achieved with the weighting of sample in the first bin (Figure 2). Obviously, Figure 2 shows the cleaning of pure sunflower seed from leaves and ray flowers carried out in the whole of treatment. Very few seeds with medium size dropped in the first bin.

Figure 2 The sample of seed sunflower separation in the best treatment combination 60 rpm, 6cm and 20 kV

The ideal separation is achieved when that the weight of sample be equal to 12 g in the first bin. It means that all of 12 g pure sunflower seed deposited in the first bin. To study the effect of selected independent variables on the separation of pure sunflower seeds, statistical analysis was performed on the data. In the following, the effects of roll rotational speed, corona electrode distance from roll and DC power supply voltage (as effective factors in roll-type corona separator) are investigated with linear regression model on sunflower seed separation.

3.1 The linear regression model

The linear regression model was used for expression of the sunflower seed separation according to independent factors variation. The linear regression model showed a high correlation coefficient. The results of the analysis of variance for linear model are presented in Table 1.

Table 1 Analysis of variance for linear regression model

Model	Degree of freedom	Means squares	Sig.
Regression	3	123.159	0
Residual	77	1.015	
Total	80		

This linear regression model was significant for the sunflower seeds prediction in probability level of 5% ($p<0.05$ as level of significant). The results showed that the model is able to predict the separation with variation of electrode distance from roll, rotational speed and power supply voltage. Standardized coefficients and unstandardized coefficients are presented in Table 2.

Table 2 Unstandardized and standardized coefficients of the linear regression model

Regression coefficient	Unstandardized coefficients	Standardized coefficients
Intercept	–11.432	–
Electrode distance from roll	1.403	0.487
Rotational speed	0.201	0.698
Power supply voltage	–0.092	–0.318

According to standardized coefficients of the regression model, the power supply voltage has reduction effect on the seed separation whereas the rotational speed and electrode distance from roll has additive effects. Also, standardized coefficient of rotational speed is more than standardized coefficient of power supply voltage and electrode distance from roll, so the rotational speed has greater impact on separation. Forces acting on insulating particles (nonconductive particles) in Roll-Type Corona-Electrostatic Separators are the electric image force (F_i), centrifugal force (F_c) and the gravitational force (F_g). Particles detach from the rotating electrode (roll) when the resultant of gravitational and centrifugal forces surpasses the pinning action of the electric image force (Younes et al., 2013). The particles charge, purity and separating efficiency of corona electrostatic separator from the point of view of electrostatics and mechanics are affected by the main factor of rotational speed (Li et al., 2008). The centrifugal force increases with increasing of rotational speed. So, the big sunflower seed separate from roll electrode surface because of the high mass density. Also in the higher speed, the surface charge of seeds and subsequently the image force decreases in a given voltage (Samuila et al., 1997).

According to standardized coefficient in Table 2, The linear regression model for the weight of pure sunflower seed in the first bin under the roll electrode (Y, g), Electrode distance from roll (X_1, cm), Rotational speed (X_2, rpm) and Power supply voltage (X_3, kV) is equal to:

$$Y = +0.487\times(X_1) + 0.698\times(X_2) - 0.318\times(X_3)$$

Coefficient of determination (R^2) was obtained 0.95 for this equation which expression the variation of seed separation by means of three factor (Power supply voltage, Electrode distance from roll and rotational speed). With according to the more coefficient of determination, this model is able to estimates the separation efficiency. For model validation, the measured value of seed separation fitting than the predicted value which the result showed the more correlation (Figure 3).

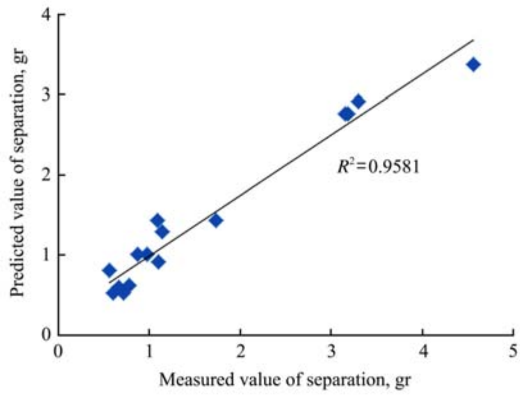

Figure 3 The accuracy of model for seed sunflower separation against measured values

3.2 The germination in corona field

Sunflower seed was separated with roll-type corona separator. The results of experiment showed that the maximum separation occurred at in the treatment combination 60rpm, 6cm and 20kV (Figure 2). So the test sample of sunflower (sorted) was selected from the mentioned treatment combination for germination. The sunflower seeds (sorted and unsorted) planted in a pot filled with soil in the form of factorial analysis based on a completely randomized design with three replications. Table 3 shows analysis of variance the sunflower seeds germination (corona treatment and without it).

Table 3 Analysis of variance the sunflower seeds germination

Source of variation	Degree of freedom	Sum of square	Mean of square
Treatment	1	1.870	1.870^ns
Experimental error	4	47.059	18.515
Total	5	75.930	-

Note: ns: not significant (p<0.05).

The coefficient of variation (CV) represents the ratio of the standard deviation to the mean. The coefficient of variation for the sunflower seeds germination experiment was 4.75%. The lower CV shows that the germination experiments were performed with high precision. Statistical processing of the data shows that the increase in viability of the seeds treated with corona discharge field is no substantial in comparison with the control (unsorted seed). According to Table 3, no significant differences were found between the treatments on the sunflower seed germination in 5% probability level (p<0.05). This means that the corona electric field doesn't change the sunflower seed germination in the treatment combination (60 rpm, 6 cm and 20 kV) as ideal separation in the roll-type separator. It was demonstrated that rice seeds subjected to electric field have higher growth rates (about 5%-10%), but electric field has no effect on the germination (Kerdonfagetal, 2002). About the effect of electric field, Isobe et al. (1998) stated that electric polarization of the membrane system causes have abnormal accumulation of water in the plant. These factor lead to inflation and break the membrane systems and consequently causes to irregular shape of tissues. These reasons may increase germination rate (Isobe et al., 1998). Basiry and Esehaghbeygi (2012) showed that no significant effects were observed on the germination improvement of wheat and canola, but a significant difference was observed between sorted and unsorted barley seed germination percentages. The improvement gained in barley seed germination was 17.34% higher as compared with unsorted seed. Lynikiene et al. (2006) showed that the seeds affected by corona discharge field germinate faster than those non-affected do, and seeds germination dynamics is greater. Due to the influence of the stimulating field, carrot seed viability increased by 24%, that of radish and beetroot by 12%, beet seeds by 7% and barley seeds by 9%.

4 Conclusions

The electrostatic separator with three wire-type electrodes developed in this work was able to separate pure sunflower seeds from MOG. No intact seeds and particles that are relatively poor conductors, like straws, adhered to the belt. These particles lost their charges gradually and fell into the subsequent bins. The whole complex of the electrical and mechanical characteristics of the seeds should be used in order to achieve separation of sunflower seeds. According to the linear regression model, the roll rotational speed (between all of effective factors) has greater impact on pure sunflower seed separation. The results of germination dated showed that no significant difference was found between the treatments (sorted and unsorted) on the sunflower seed germination at 5% probability level (p<0.05) and the corona electric field doesn't have effect on sunflower seed germination in roll-type corona discharge separator. The ideal separation was accrued in treatment combination at 20 kV, 6 cm and 60 rpm for the pure sunflower seed.

References

Basiry, M., and A. Esehaghbeygi. 2012. Cleaning and charging of seeds with an electrostatic separator. *Applied Engineering in Agriculture*, 28(1): 143–147.

Borodin, I., and K. Scerbakov. 1998. Electrophysical ways of stimulating plant growth (in Russian). *Machinery in Agriculture*, 5: 35–35.

Carbonell, M. V., E. Martinez, A. Raya, and J. M. Amaya. 2000. Effects of 125 mT stationary magnetic field in the initial stages of growth of wheat (*Triticum durum* L.). *Žemės Ūkio Inžinerija, Mokslo Darbai*, 32(3): 5–10.

Dascalescu, L., A. Mizuno, R. Tobazeon, P. Atten, R. Morar, A. Iuga, M. Mihailescu, and A. Samuila. 1995. Charges and forces on conductive particles in roll-type corona-electrostatic separators. *IEEE Transactions on Industry Applications*, 31(5): 947–956.

Dascalescu, L., R. Morar, A. Iuga, A. Samuila, and V. Neamtu.

1998. Electrostatic separation of insulating and conductive particles from granular mixes. *Particulate Science and Technology*, 16(1): 25–42.

Davies, M. S. 1996. Effects of 60Hz electromagnetic fields on early growth in three plant species and replication of previous results. *Bioelectromag*, 17(2): 154–164.

Harmond, J. E., N. R. Brandenburg, and L. M. Klein. 1968. *Mechanical Seed Cleaning and Handling.* Agricultural Handbook, No. 334. Washington, D.C.: Agric. Res. Ser., U.S. Dept. Agric. Coop. Oregon Agri. Exp. Stat.

Isobe, S., N. Ishida, M. Koizumi, H. Kano, and C. F. Hazelwood. 1998. Effect of electric field on physical states of cell-associated water in germinating morning glory seeds observed by 1 H-NMR. *Biochimica et Biophysica Acta (BBA)-General Subjects,* 1426: 17–31.

Kerdiunfag, P., C. Klinsa, and W. Khan. 2002. Effect of electric field from the electric field rice grain separation unit on growth stages of rice plant. *ICEMC,* 4(1): 250–254.

Konchenko, N. F., and S. K. Trofimov. 2000. Increase of seeds quality. *Technique in Agriculture,* 3(1): 6–8.

Krishnan, P., A. G. Berlage, and E. Klein. 1985. Electrostatic separation of flower parts from onion seeds. *Transactions of the ASAE*, 28(5): 1676–1679.

Leonov, V. S. 1984. Seed divisibility criteria during electrical separation. *Mekhanizasiya I Elektrifikatsiya Sotsialistcheskogo Sel skogo Khozyiastv*, 4(2): 47–49.

Li, J., H. Lu, Z. Xu, and Y. Zhou. 2008. Critical rotational speed model of the rotating roll electrode in corona electrostatic separation for recycling waste printed circuit boards. *Journal of Hazardous Materials*, 154(1-3): 331–336.

Lynikiene, S. 2001. Carrot seed preparation in a corona discharge field. *Agricultural Engineering International: CIGR Journal*, 3: FP 00021.

Lynikiene, S., A. Pozeliene, and G. Rutkauskas. 2006. Influence of corona discharge field on seed viability and dynamics of germination. *International Agrophysics*, 20(3): 195–200.

Lynikiene, S., and A. Pozeliene. 2003. Effect of electrical field on barley seed germination stimulation. *Agricultural Engineering International: CIGR Journal*, 5: manuscript No. FP 00 021.

Molamofrad, F., M. Lotfi, J. Khazaei, R. Tavakkol-Afshari, and A. A. Shaiegani-Akmald. 2013. The effect of electric field on seed germination and growth parameters of onion seeds (*Allium cepa*). *Advanced Crop Science,* 3(4): 291–298.

Morar, R., A. Iuga, L. Dascalescu, and A. Samuila. 1993. Factors which influence the insulation-metal electroseparation. *Journal of Electrostatics*, 30(1): 403–412.

Palov, I. 2003. Research of influence of electromagnetic impact on maize seed and plants (in Bulgarian). *Machinery in Agriculture*, XL(1): 10-15.

Pozeliene, A., S. Lynikiene, I. Sapailaite, and A. Sakalauskas. 2008. Utilization of strong electric field for special cleaning buckwheat seeds. *Agronomy research*, 6(special issue): 291–298.

Putincev, A. F., and N. A. Platonova. 1997. Treatment of seed in electromagnetic field. *Agriculture*, 4(1): 45–49.

Samuila. A., A. Iuga, R. Morar, R. Tobazéon, and L. Dascalescu. 1997. Factors which affect the corona charging of insulating spheres on plate and roll electrodes. *Journal of Electrostatics*, 40-41(2): 377–382.

Urs. A., A. Samuila, A. Mihalcioiu, and L. Dascalescu. 2004. Charging and discharging of insulating particles on the surface of a grounded electrode. *IEEE Transaction on Industry Application*, 40(2): 437–441.

Younes. M., A. Younes, H. Sayah, A. Tilmatine, A. Samuila, and L. Dascalescu. 2013. Numerical and experimental study of insulating particles behavior in roll-type corona-electrostatic separators. *Particulate Science and Technology*, 31(1): 71–80.