DETERMINATION OF PERFORMANCE CHARACTERISTICS OF HORIZONTAL WIND TUNNEL IN THE CLEANING OF CORN-COB MIX
/
MISIR-KOÇAN KARIŞIMININ TEMİZLENMESİNDE YATAY HAVA TÜNELİNİN PERFORMANS KARAKTERİSTİKLERİNİN BELİRLENMESİ

Ress.Assist. Karaköse T. *[1], Assist.Prof.Dr. Tekgüler A.[2]
[1]Ondokuz MayisUniversity, Faculty of Agriculture, Atakum / Turkey
[2]Ondokuz Mayıs University, Samsun Vocational School, İlkadım / Turkey
Tel: +903623121919; E-mail: tugba.karakose@omu.edu.tr

Keywords*: horizontal air tunnel; cleaning efficiency; loss ration*

ABSTRACT

In the cleaning process, different relative velocities of the grains through the air stream are utilized. The purpose of this study is to determine parameters such as fan angle, material feed rate and air velocity which will ensure separation of corn. Cleaning efficiency increased with increasing fan angle and air velocity and decreased with increasing feed rate. Loss rate increased with increasing fan angle and air velocity, and decreased with increasing feed rate.

It can be said that the most appropriate combination (89.79% cleaning efficiency and 0.24% loss rate) was the application at 30° fan angle, 1152 kgh^{-1} feed rate and 15 ms^{-1} air velocity.

ÖZET

Aerodinamik temizlemede, hava akımı içinde tanelerin farklı bağıl hızlarından yararlanılır. Bu çalışmada, mısırın temizlenmesini sağlayacak; fan açısı, materyal besleme oranı ve hava hızı gibi parametreleri belirlemektir. Temizleme etkinliği, fan açısı ve hava hızı arttıkça artmakta, besleme oranı arttıkça azalmaktadır. Fan açısı ve hava hızı arttıkça kayıp oranı artmakta, besleme oranı arttıkça kayıp oranı azalmaktadır.

En uygun kombinasyonun (%89.79 temizlemeetkinliğive %0.24 kayıporanı) 30° fan açısında, 1152 kgh^{-1} besleme oranında ve 15 ms^{-1} hava hızındaki uygulama olduğu söylenebilir.

INTRODUCTION

A great majority of food needs are met from the grains. In the world, corn is in the third place after the wheat and paddy in terms of production areas, and the first in the production amount (URL-1). In Turkey, according to the data of 2014, it is in the 3rd place in the production of cereals, in terms of production area and amount of production (URL-2).

Corn usage areas increase day by day. In addition to this, it is more important than other grains for reasons such as being easy to grow and drought-tolerant, effective photosynthesis even at low CO_2 ratios, being more resistant to diseases and damages, having high ability to use light intensity and high water use efficiency.

Even if the most modern harvesting machines are used, grain products cannot be assessed immediately as they are obtained *(Tekin Y., 1995).*Agricultural products need a sequence of processes such as cleaning, classification, drying, storage, etc. in order to make them available. These processes preserve the nutritional and commercial value of the product *(Yağcıoğlu A K, 2009).* Cleaning is separation of the straw, mud, stone, soil, foreign seed etc. material in the product from the original product. Cleaning and classification of granular products can be performed according to different physico-mechanical properties. These are geometric properties, aerodynamic properties, surface structure, mechanical properties, specific gravity, electrical and optical properties.

According to the aerodynamic characteristics, different relative velocities of the grains are utilized in the airflow during cleaning *(Berber S, 2007).* Air velocity that can suspend grain in the air is called critical speed. If the critical speeds of each material forming any mixture are sufficiently different from each other, these materials can be separated from each other *(Yağcıoğlu A K, 2009).*If there is a big difference between the critical speeds, it increases the success of the separation process *(Pasikatanand Quick, 1995; Tabatabaeefar et al., 2003).*

Air flow separators or pneumatic cleaners are used to clean products from foreign materials by means of air flow.In the pneumatic cleaning process, the flow direction of the air can be horizontally between 0°-90°.In pneumatic cleaners where the air flow is in the vertical direction (90°), the suspension of main materials within the air flow is made use of. Pneumatic cleaners where the air flow is in the horizontal direction (0°) make use of materials that enter the air in the direction perpendicular to the flow and of their being dragged away by drawing different orbits horizontally.

Pneumatic cleaners consist essentially of air canal and air flow generators (fans). These cleaners operate according to the principle of absorption or pressurization of air to air canal. The air velocities in each section taken along the length and width of the air channel are wanted equal to each other, in order to ensure high separation efficiency and low seed loss during cleaning *(Evcim Ü, 1991; Yağcıoğlu A K, 1996).*

In *Adewumi*'s (2008) study, horizontal air tunnel was used to classify cowpea, according to size and density in terms of aerodynamic principles. The results showed that 12 ms^{-1} air velocity and 22.5° fan angle were most appropriate.

Simonyan and Yiljep (2008) used the cleaning unit of traditional thresher to determine the separation and clean up efficiency values of sorghum. Cleaning losses increased with increasing feed rate and air velocity. The highest separation efficiency was found as 99.85%. Air velocity raise increased with the loss rate and up to 54% lost product was observed in different feed amount.

Rouzegar et al. (2013) used a horizontal air tunnel to determine the effect of humidity, air velocity and feed rate on rice separation efficiency. They achieved the highest separation efficiency at 850 rpm fan speed. Separation efficiency increased with rising humidity and feed ratio. Compared to a mechanical system, they reported that this machine, operating according to pneumatic principles, is economical because of its high separation efficiency, low loss rate and low power consumption. *Beyhanve Erol* (1993) has made a study to determine the aerodynamic characteristics of some hazelnut varieties of grains and hazelnuts. In the study, they found that the critical rates of grain and hazelnuts varied between 7-14 m s^{-1}

The purpose of this study, is to determine design parameters such as fan angle, material feed rate, air velocity and air tunnel length to provide separation of corn mixture consisting of grain and cob parts.

MATERIAL AND METHODS

An experimental mechanism has been prepared in which air velocity, fan angle and feed rate can be adjusted (Fig. 1). Mechanism consists of the fan, the product storage, the feeding unit, the air canal and collection boxes.

Fig. 1 - Experimental mechanism

Fan characteristics used to obtain airflow are given in Table 1.

Table 1

Fan characteristics

Number of wings (number)	8
Air outlet section (mm)	190x70
Internal diameter of fan (mm)	150
External diameter of fan (mm)	400
Width (mm)	200
Rotation(min^{-1})	1100-1300-1500-1750-1950
Flow (m^3s^{-1})	0.1995-0.2394-0.2793-0.3192-0.3591

The power of the electric motors acting on the fan and the supply units are 0.75 kW and 3 kW, respectively. The experimental mechanism is used for uniform material flow. The length of the air tunnel is 800 mm. Two different product collection boxes of 400 and 800 mm from storage outlet section were used.

Experiments were conducted with *zea mays indentata sturt* corn grains and their cobs. The sizes of corn cobs are reduced by crushing in the hammer mill. During the course of the experiment, the grain moisture varied between 15-16%. A mixture of 8 kg was prepared. It was arranged so as to include 85% corn and 15% stubble. The amount of this mixture was kept constant throughout all experiments.

Feed rates of 240, 576, 822, 1152 and 1600 kgh^{-1}were created by changing the sections of the storage outlet. Experiments used air velocities of 15, 18, 21, 24 and 27ms^{-1}.These air velocities were obtained with the frequency converter shown in figure 2.2, by varying the revolutions per minute of the electric motor which drives the fan. Anemometer was used to measure air velocities.

The position of the fan with the test mechanism can be adjusted to make horizontal angles of 15°, 30° and 45°.The mixture of corn and cob, which falls into the air canal from storage and encounters the air flow provided by the fan, falls into the product collection boxes at different distances. The grains and cobs collected in these boxes were separately weighed with a precision scale.

The product cleaning efficiency and loss ratio of grain-cob quantities obtained as a result of the weighing were determined using the following equations *(SimonyanandYiljep, 2008).*

Cleaning efficiency:

$$CE = \left(\frac{Go}{G1}\right) * 100 \tag{1}$$

Where:

CE- the cleaning efficiency (%)

Go - grain weight at outlet (kg)

G1 -total mixture weight at outlet(kg)

Loss ratio:

$$LR = \frac{\mathrm{G\dot{I}}}{\mathrm{Gw}} * 100 \tag{2}$$

Where:

LR - Rate of grain loss in cleaning units (%)

Gi - Weight of grain thrown out of the air tunnel (kg)

Gw - Grain weight in the mixture filled in the feeding unit (kg)

For each application of 5 different feed rates, 5 different air speeds and 3 different fan angles were made with four repetitions. To determine the effect of these factors, the obtained data were analysed according to the 3-factorial design in randomized blocks in the JUMP 5.0.1 statistical program. The results were compared with the LSD test.

RESULTS

According to the analysis of variance, interactions of the fan angle, feed rate and air velocity were found to be significant for clearing efficiency (CE) and loss ratio (LR) ($p < 0.01$). CE for the first collection box varied between 85-100%, LR varied between 0.24-93.01%.

The CE and LR variations at 45°, 30° and 15° fan angles are given in Fig. 2.At 45° fan angle, CE values varied between 99.65-89.58% and LR values varied between 92.42-3.21%.The highest CE value (99.65%) was detected at the feed rate of 576 kgh^{-1} and at the air velocity of 21 ms^{-1} while the lowest LR value (15.2%) was detected at the feed rate of 1152 kgh^{-1}and the air velocity of 15ms^{-1}.

At 30° fan angle, CE values varied between 99.16-87.17% and LR values varied between 50.70-0.24%. The highest CE value (99.16%) was detected at the feed rate of 822 kgh^{-1}and the air velocity of 27 ms^{-1}, while the lowest LR value(0.24%) was detected at the feed rate of 1152 kgh^{-1}and the air velocity of 15 ms^{-1}.

At 15° fan angle, CE values varied between 95.86-85.06%and LR values varied between18.73-0.39%. The highest CE value (95.87%)was detected at the feed rate of 576 kgh^{-1}and the air velocity of 27 ms^{-1}, while the lowest LR value(0.39%) was detected at the feed rate of 240 kgh^{-1}and the air velocity of 15 ms^{-1}.

In previous studies, cleaning efficacy values were determined as 42-80% for corn *(Hurburgh et al., 1989)* 80%, 94%, 98% for oat, wheat and rye respectively *(Uhl and Lamp, 1966),* 93% for Chickpea *(Tabatabaeefar et al., 2003),* 99.85% for sorghum *(Simonyan, Yiljep, 2008),*87.2% for the yellow bitter variety (Amulet lupine) *(Panasiewicz et al., 2011).*

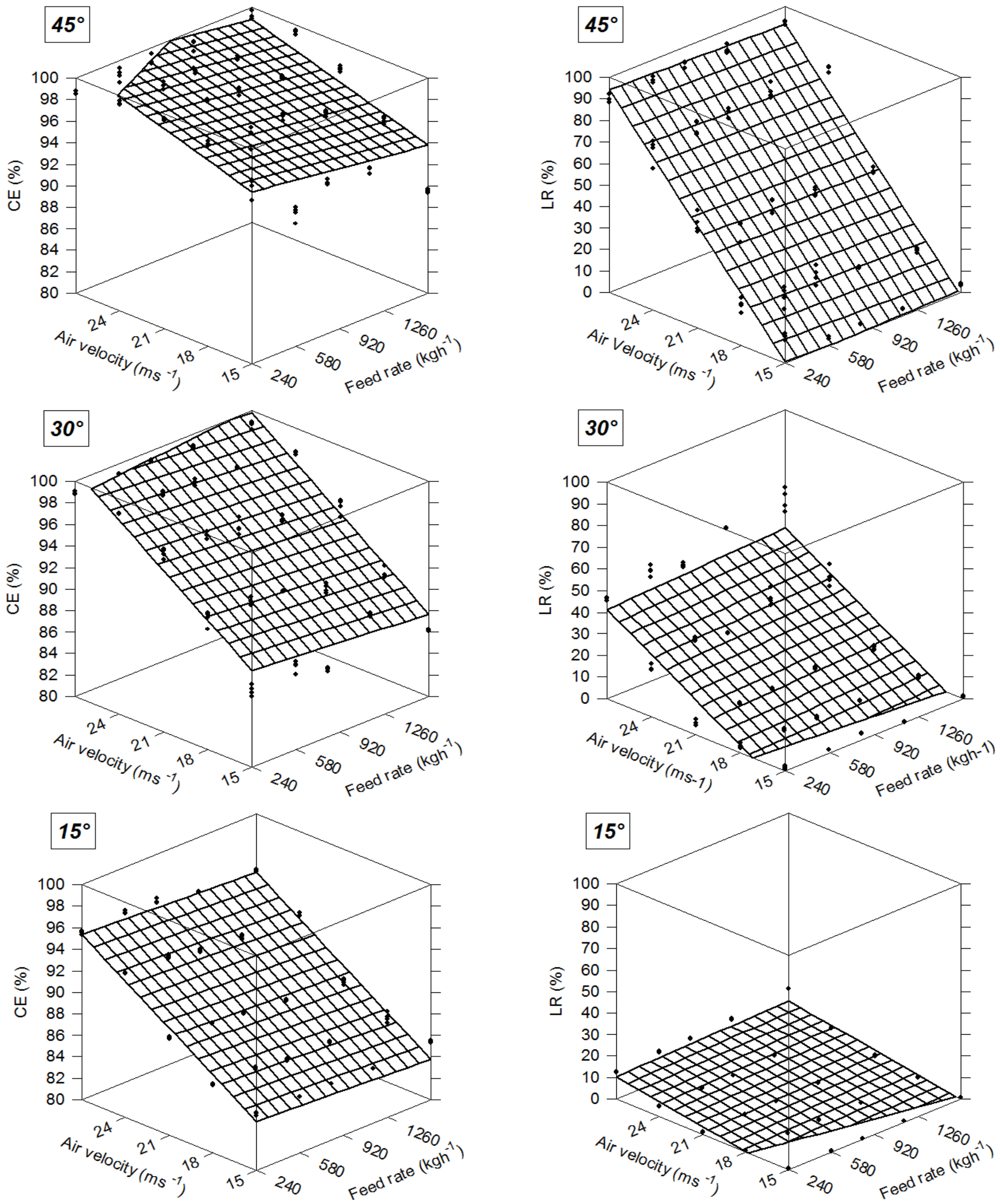

Fig. 2 - The first collecting box, CE and LR variation at 45°, 30° and 15° fan angles

CE for the second collection box varied between 85-100%, LR varied between 0.13-70%.

Fig.3 shows the change of CE and LR at 45°, 30° and 15° fan angles according to the feed rate and air velocity.

At 45° fan angle, CE values varied between 98.73-86.45% and LR values varied between69.17-1.85%. The highest CE value (98.74%) was detected at the feed rate of 576 kgh^{-1} and the air velocity of 21 ms^{-1}, while the lowest LR value (1.85%) was detected at the feed rate of 1152 kgh^{-1} and the air velocity of 15 ms^{-1}.

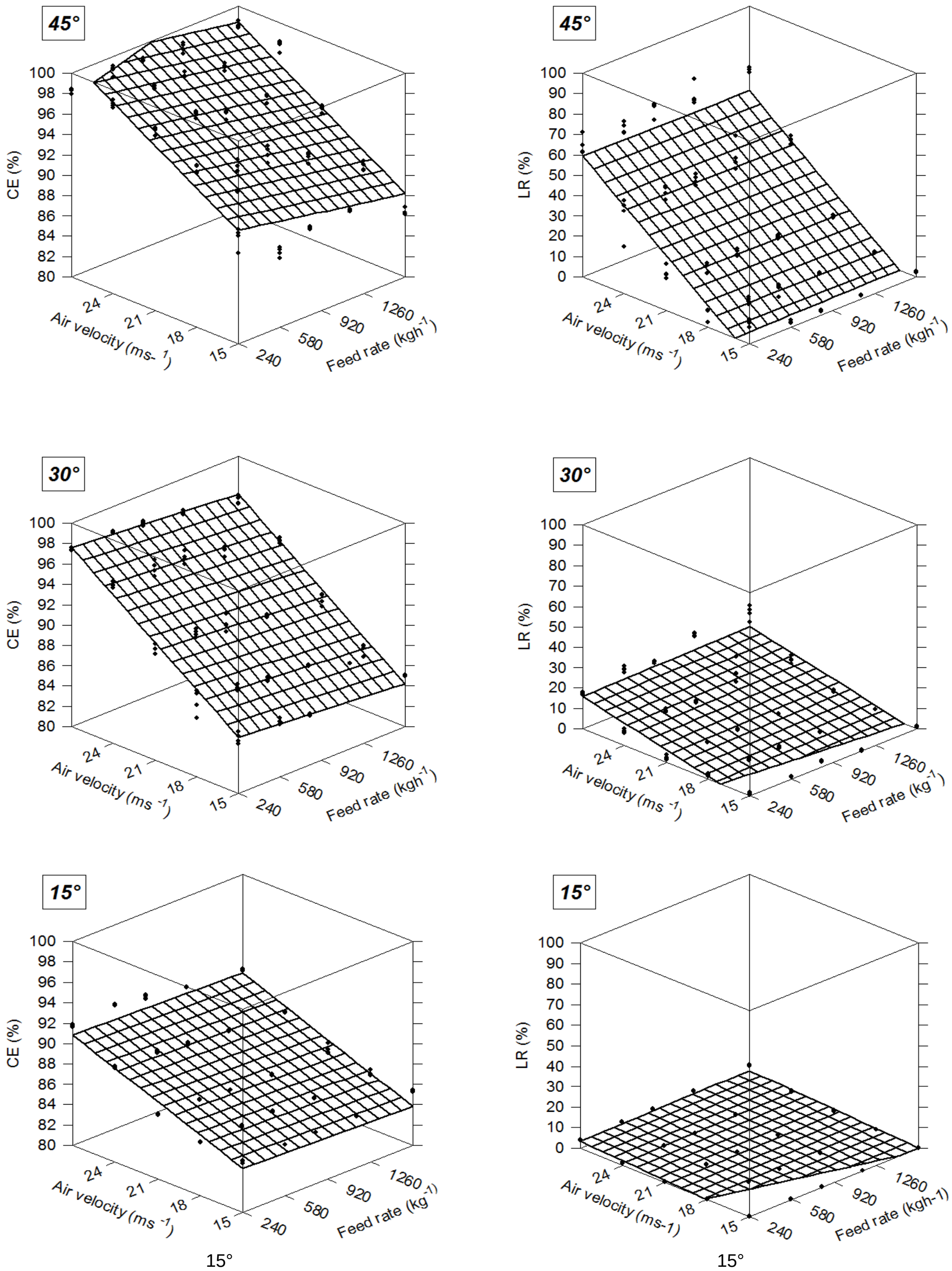

Fig. 3 - The second collecting box, CE and LR variation at 45°, 30° and 15° fan angles

At 30° fan angle, CE values varied between 97.58-85.01% and LR values varied between24.50-0.13%. The highest CE value (98.59%) was detected at the feed rate of 576 $kgh^{-1}$and the air velocity of 27 ms^{-1}, while the lowest LR value (0.13%) was detected at the feed rate of 1152 $kgh^{-1}$and the air velocity of 15 ms^{-1}.

At 15° fan angle, CE values varied between 92.21-85.00 % and LR values varied between 7.22-0.15%. The highest CE value (92.21%) was detected at the feed rate of 576 $kgh^{-1}$and the air velocity of 27 ms^{-1}, while the lowest LR value (0.15%) was detected at the feed rate of 24 $kgh^{-1}$and the air velocity of 15 ms^{-1}.

CE values in the first box were higher than in the second box, while LR values were lower. For the first collecting box, the highest CE value (99.65%) was seen at45° fan angle, 576 kgh^{-1} feed rate and 21 ms^{-1} air velocity while the lowest CE value (85.07%) was observed at 15° of fan angle, 1152 kgh^{-1} of feed rate and 15 $ms^{-1}$of air velocity.

For the second collecting box, the highest CE value (98.74%) was seen at 45° fan angle, 576 kgh^{-1} feed rate and 27 ms^{-1} air velocity while the lowest CE value (85.01%) was observed at 15° of fan angle, 240and 576 $kgh^{-1}$of feed rate and 15 ms^{-1} of air velocity.

For the first collecting box, the highest LR value (93.01%) was seen at 45° fan angle, 1600 kgh^{-1} feed rate and 27 ms^{-1} air velocity while the lowest LR value (0.24%) was observed at 30° of fan angle, 1152 kgh^{-1} of feed rate and 15 ms^{-1} of air velocity.

For the second collecting box, the highest LR value (69.17%) was seen at 45° fan angle, 1600 kgh^{-1} feed rate and 27 ms^{-1} air velocity while the lowest LR value (0.13%) was observed at 30° of fan angle, 1152 kgh^{-1} of feed rate and 15 ms^{-1} of air velocity. Cleaned products reduce product loss due to the increased air tunnel length from the feed outlet side.

Sorghum has been found to have product loss up to 54% *(Simonyan and Yiljep, 2008).* Uhland Lamp (1966) stated that it is not possible to clean corn without loss of grain.

CONCLUSIONS

In the study for corn cleaning in the horizontal air tunnel, CE and LR values varied depending on the length of the air tunnel, air speed, feed rate and fan angle. The highest CE (99.65%) was determined at45° fan angle, 576 kgh^{-1}feed rate and 21 ms^{-1} air velocity in the first collection box. The least LR (0.13%) was determined at 30° fan angle, 1152 kgh^{-1} feed rate and 15 ms^{-1} air velocity in the second collection box.

The applications below 1% of LR in the first collection box, in which CE is high, are given in Table 2.

Table 2

Best applicationsinthe first box according to cleaning efficiency and loss rate

CE (%)	LR (%)	Fan angle (°)	Feed rate (kgh^{-1})	Air velocity (ms^{-1})
89.79465	0.24173	30	1152	15
86.33599	0.53313	15	240	18
86.23009	0.59268	15	576	18
85.86218	0.89735	15	1152	18
85.84654	0.98743	15	822	18
85.39345	0.82482	15	1600	15
85.26317	0.39235	15	240	15
85.23333	0.58316	15	822	15
85.23089	0.49364	15	576	15
85.06529	0.58882	15	1152	15

As it can be seen in Table 2, we can say that the best application were at the fan angle of 30°, feed rate of 1152 kgh^{-1} and air velocity of 15 ms^{-1} (89.79% CE and 0.24% LR).

As a result of the study findings evaluation, we can list the suggestions as follows:

- 15-21 ms^{-1}air velocity was found suitable for separation of corn-cob mixture in the horizontal air tunnel. LR increases at higher speeds.
- CE values are higher at 45° fan angle because the air entering the air canal at a more vertical angle causes the product to be cleaned more effectively. However, LR values were found to be high at this angle.
- There are differences between collection boxes in terms of CE and LR. While CE increases in the first box, LR decreases in the second box. If the product evaluated as loss can be returned to the storage, the first box (40 cm) should be preferred because of higher CE.

ACKNOWLEDGEMENT

This study was the summary of the master thesis which was directed by Ass.Prof.Dr. Ali TEKGÜLER and was accepted in the Institute of Science of Ondokuz Mayıs University in 2016.

REFERENCES

[1] Adewumi B.A., (2008), 2D Modeling of grain transport and separation in the horizontal air stream, *ASABE Publication, Food Processing Automation Conference CD-Rom, Proceedings of the 28-29 June 2008 Conference, Providence, Rhode Island, ASABE Publication Number 701P0508cd;*

[2] Adewumi B.A., Sathyendra Rao B.V., Kıran Kumar N.L., Pratape V.M., Srinivas A., (2007). Grain classification using aerodynamic principles, *African Crop Science Conference Proceedings*, Vol.8, pp.1799-1801;

[3] Adewumi B., Ademosun O., Ogunlowo A., (2006), Preliminary investigation on thedistributionand spread pattern of cowpea in a cross flow grain separator. *Agricultural Engineering International*: The CIGR E journal. Manuscript FP 06 020, Vol. VIII, pp.1-12, India;

[4] Berber S., (2007), *Determination of aerodynamic properties of safflower (Carthamus Tinctorious. L.*) *seeds,* M.Sc. Thesis. Gaziosmanpaşa University. Institute of Science and Technology. Tokat;

[5] Beyhan M.A., Erol M.A., (1993). The aerodynamic characteristics of huskand grain of some hazelnut varieties, *Proceedings of 5thInt. Cong. On Mechanization and Energy in Agriculture*, pp.472-483, Kuşadası / Turkey;

[6] Evcim Ü., (1991), *Product cleaning and sorting technology*, Ege University Agricultural Faculty Press, p.110, İzmir;

[7] Hurburgh C.R., Bern C.J., Brumm T.J., (1989), Efficiency of rotary grain cleaners in dry corn, *Transactions of the ASAE*, 32 (6), pp. 2073-2077;

[8] Panasiewicz M., Zawiślak K., Kusińska E., Sobczak P., (2008), Purification and separation of loose materials in a pneumatic system with vertical air stream, *TEKA Kom. Mot. Energ. Roln.–OL PAN*, vol:8, pp.171–176;

[9] Panasiewicz M.,Sobczak P., Mazur J., Zawis´Lak K., Andrejko D., (2011), The technique and analysis of the process of separation and cleaning grain materials, *Journal of Food Engineering*, vol.109, pp.603–608, Elsivier;

[10] Pasikatan M.C., Quick G.R., (1995), A review of oscillating screen-blower cleaners for grains, *Philippine Engineering Journal* XVI (2): pp.77-97, Philippines;

[11] Pasikatan. M.C., Quick. G. R., Barredo I. R., Lantin. R. M., (1996), *A Compact triple airstream. triple-screen rice seed cleaner*, Philipp J. CropSci., 21 (3), pp.53-60;

[12] Rajabipour A., (2004), Moisture-dependent terminal velocity of wheat and rice varieties, *ASAE/CSAE Annual International Meeting*. paper number:046008, Ottawa. Ontario, Canada;

[13] Rouzegar M. R., Asli-Ardeh E. A., Abbaspour-Gilandeh Y., Khalifeh A. A., (2013). Study effects of moisture content, feed rate and fan revolution on separation efficiency in a paddy laboratory winnower, *International Journal of Agriculture and Crop Sciences (IJACS)*, Vol. 5(21), pp.2576-2578, Elsivier;

[14] Simonyan K.J., Yiljep Y.D., (2008). Investigating grain separation and cleaning efficiency distribution of a conventional stationary rasp-bar sorghum thresher, *Agricultural Engineering International: The CIGR E-journal Manuscript* PM 07 028. Vol. X, pp.1-13;

[15] Tabatabaeefar A., Aghagoolzadeh H., Moblı H., (2003). Design and development of an auxiliary chickpea second sieving and grading machine, *Agricultural Engineering International: CIGR Journal of Scientific Researchand Development.* Manuscript FP 03 005, Vol.V, 1-8;

[16] Tekin Y., (1995), Product cleaning and sorting technology, *Özdaş K., Agricultural Tools and Machinery*, 4th edition, pp.297-318, Anadolu University, Eskişehir;
[17] Uhl J.B., Lamp. B.J., (1966), Pneumatic separation of grain and straw mixtures. *Transactions of the ASAE*, vol.9, pp.244-246.
[18] Yağcıoğlu A.K., (2009), Post-harvest processing technology, Editor: Prof. Dr. G. Güneş, Agricultural machines, 1st edition, Nobel Publication and distribution, Ankara, pp.488-491;
[19] URL-1 http://www.tmo.gov.tr/Upload/Document/hububat/hububat%20raporu.pdf(ZiyaretTarihi:02.06.2 016/ 10.04);
[20] URL-2 http://www.tuik.gov.tr/UstMenu.9do?metod=temelist(ZiyaretTarihi:02.06.2 016/ 10.11).