Comparison of mechanical Z-shape elevator operation for handling seed corn

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Abstract: Handling systems in seed processing factories inflict impressive damages on seed corn. It was reported 24% of damages on seed corns related to elevators. In current research, the operation of a Z-Shape elevator was studied and compared to conventional bucket elevator which employed in two seed drying stations of Seed and Plant Improvement Institute in Karaj city and Shahi plant in Moghan plain, Iran. The effect of elevator operation on seed cracking and breakage was determined by t-test. According to the results, applying Z-Shape elevator decreased the physical seed damages up to 78% and reduced the chance of seed cracking between 4% to 8% in comparison with conventional elevators. Economically results illustrated spending the cost equal to 10% of the loss funds which was accrued due to employing conventional elevators, could decrease damages until 90% in Moghan plain.

Keywords: conveying system, corn, loss, seed, Z-shape elevator

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1 Introduction

Corn drying is one of the chain loop components of seed processing factories. During the drying process of this grain, the initial moisture content of the seed decreases from 20% to 12%-14% (w.b.) (Anonymous, 2002; Somchart et al., 1999; Morey et al., 1980). Seed loss was reported in Moghan Plain during corn harvesting and drying process about 15% (Gazor et al., 2017). Incorrect utilization of the seed handling system caused to increase physical losses contains breakage, crushed and cracking (Anonymous, 2008; Bruere, 2008). During dealing with the damage of grains, internal cracks of the corn kernels which cause to initiate the damages, are very important. Internal cracks spread external cracks and finally result in breakage (Moreira et al., 1981). Previous researches illustrated high velocity handling and unsuitable bucket materials caused to damage seeds and conveyor components (Henderson and Perry, 1976; Birenbaum and Rudnitski, 1989). Also, high moisture content of seeds increased the level of damages significantly (Wayne et al., 2004). Pliestic and Sutalo (2001) expressed that conveyor velocity increment was caused to increase the physical damages of seed corns with initial moisture content of 11%-30% (w.b.). According to the results, decreasing the moisture content of seeds to 11% (w.b.) caused to increase seed breakage to 2.57%. Researches on seed corn

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production in Argentina evidenced unsuitable drying process and handling caused to increasing seed damages further than 50%. Improve dryers and elevators conditions in the factories can decrease the seed damages less than 2% (Hill, 1997).

Several experiments were conducted on seed corn at moisture contents of 7.60% to 25% (w.b.) and impact energy levels of 0.1, 0.2 and 0.3 J in order to determine damages by utilizing an impact damage assessment device. Increasing the impact energy caused a significant enhance of the mean values of damage from 23.73% to 83.49%. The mean values of physical damage was reduced significantly by a factor of 1.92 (from 83.75% to 43.56%), while the moisture content increased from 7.6% to 20% (Shahbazi, 2016). Conventional bucket elevator had a high rotational velocity so it damaged seeds further than Z-Shape elevator. Z-Shape elevators were suited for gentle handling of a broad range of bulk products in food, agriculture, pharmaceutical and chemical industries and could carefully convey from one point to another point materials like seed, grains, coffee, sweets, sugar, rice, beans, pet food and peanuts (Agrosaw, 2020).

Corn seeds damages in elevators were reported in previous literature (Pliestic and Sutalo, 2001; Wayne et al., 2004). Survey in corn drying stations evidenced using Z-Shape elevators for handling almost eliminated seed breakage and the other damages. Besides, seeds discharged from the buckets of this type elevator completely, therefore this conveyor can be applied for other seed varieties and there is no chance for mixing seeds with each other. Z-Shape elevators can be utilized to convey granular materials in different directions or pass them from any obstacle. The main objectives of this research were to compare the performance of Z-Shape elevator to conventional bucket elevator for handling of seed corn and determine seed physical damages. In the current research, the effect of applying Z-Shape elevators on reducing the seed corn losses in two seed drying stations of Seed and Plant Improvement Institute in Karaj city and Sabalan (Shahi) factory in Moghan Plain was determined.

2 Material and methods

Physical properties of corn seed (V-*Sc704*) mentioned in Table 1:

Table 1 Physical properties of Parental corn seed *Sc 704* (Seifi and Alimardani, 2010)

Moisture content (%w.b.)	Bulk density (Kg m^{-3})	True density (Kg m^{-3})	Equivalent seed diameter (mm)	Porosity (%)
4-22	649-710	1250-1325	7.36-7.96	43.2-51.02

Initially, Z-Shape elevators constructed by Azaran Iranian Bojar Company (Figure 1) were installed in two introduced corn drying stations:

1- Seed corn production factory in Seed and Plant Improvement Institute (SPII), Karaj

2- Shahi seed corn production factory, Moghan Plain

Then, operation of this type elevator was compared to conventional bucket elevators from Ar-Machine Company (Figure 2) with the same characteristics. Experimental data were evaluated by independent t-test based on standard methods of International Seed Test Association (Anonymous, 2007; Montgomery, 2009). All experiments were achieved in 5 and 3 replications in SPII and Shahi seed corn production factory, respectively.

Technical specifications of Z-Shape and bucket elevators are demonstrated in Table 2. There was no difference between the capacities of each bucket in two types of elevators, although the gearbox axes revolution of conventional bucket elevator was 80-95 rpm and about 4 times more than that in Z-Shape elevator. Moreover, in Z-Shape elevator, buckets were closer together (about 80%) in comparison with conventional bucket elevator and size of Z-Shape elevator was 20% smaller than bucket elevator. Installation area for Z-Shape elevator was 29% less than conventional bucket elevator. Seed loaded and discharged with high velocity (2.8 m s^{-1}) in conventional bucket elevators, so physical damages of seeds would be increased. While in Z-Shape elevators, buckets were loaded from a lower horizontal feeder surface with low velocity (0.2 m s^{-1}). Buckets rose slowly with an oscillation movement and seeds were discharged by a special guide.

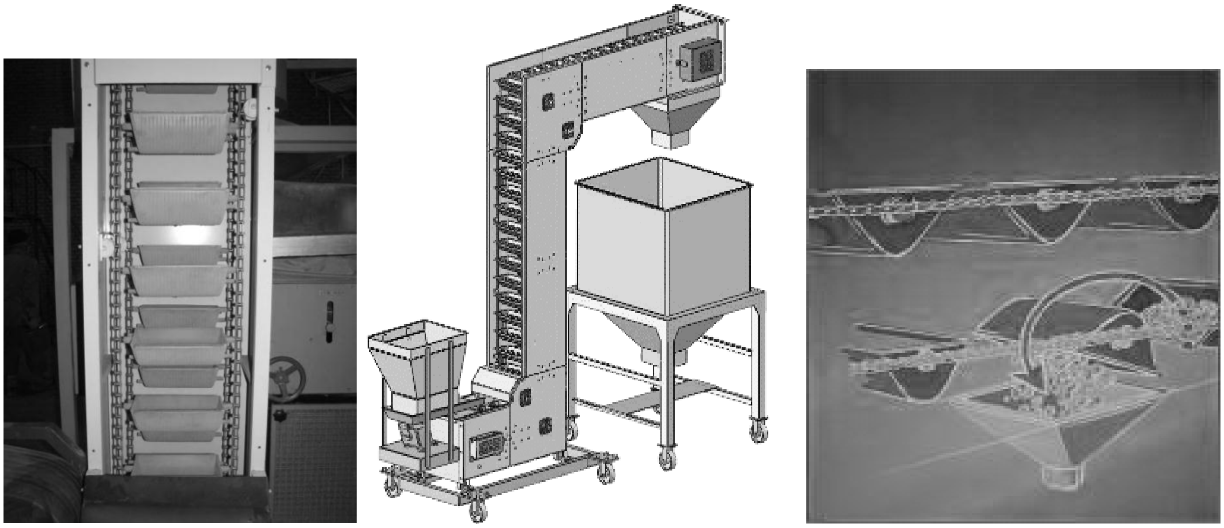

Figure 1 Z-Shape elevator (Azaran Bojar Iranian, 2019)

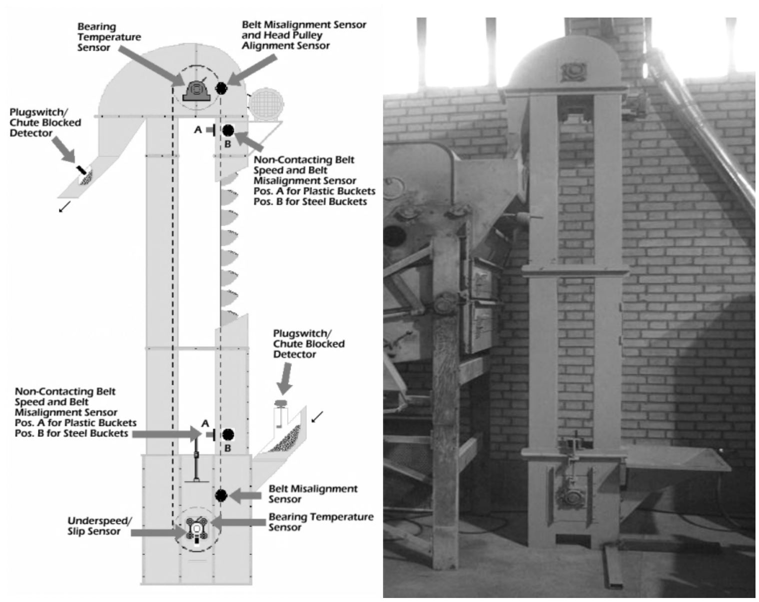

Figure 2 Conventional bucket elevator (Ar-Machine Company)

Table 2 Technical specifications of conventional bucket and Z-Shape elevators

Technical specification	Bucket elevator	Z-Shape elevator
Bucket materials	Steel (St37) plate or polyethylene	Polypropylene
Capacity of a bucker for corn carrying (g)	800-1000	800-1000
Number of buckets per meter	4 (with 25 cm distance between two buckets)	4 (Buckets are closed together)
Bucket carrier mechanism	Belt and pulley	Chain and sprocket
Seed load velocity	High velocity	Slow (by a hopper feeder with wedge shape and mass flow)
Seed discharge velocity	High velocity	Slow (into a hopper)
Minimum area for elevator installation (m^2)	1.5×2.5	1×1.1

Elevator altitude (m)	4-12	3-5 (up to 12)
Maximum seed handling capacity ($t.h^{-1}$)	4-5	4-5
Rotational speed of the gearbox axis (rpm)	80-95	17-20
Seed losses during handling	0.01% of daily capacity	Nothing
Installation and setting up	Needs to basic foundation	Easy installation

The achievements in the current research were included as bellow:

1) Technical specifications of two types of elevators contained device dimensions, required space for their installation, materials and the number of buckets per length, material and dimensions of the carrier belts and loading and discharge mechanisms were determined and compared.

2) Rotational speed of elevators' drum and their gearbox axes were measured by a tachometer "Carlo Gavazzi Pantech model, DTM30-Italy".

3) Seed breakage and cracking were determined in the elevators by sampling from their loading and discharge channels. Seeds were sized by National Standard Sieves and separated in three different dimensions of large, medium and round (Gazor et al., 2017). Also, seed corn breakage and cracking were measured based on weighing percentage using digital balance with 0.1 g precision (AND-Company, Japan) and optical seed crack detector for visual crack detection (made in Laboratory-Iran). The means weight of broken or cracked seeds calculated for each sample and divided to initial sample weight in order to present weighing percentage.

4) Conventional bucket conveyor generally used in corn seed processing plants, so it was considered as a controlled treatment in all experiments.

5) In accordance with the annual corn seed production in Moghan Plain of Ardabil province, the monetary damages which caused by conventional bucket elevator, were estimated using formula as below:

$$EED = [(BS + CS) \times PS] \times p \quad (1)$$

Where:

BS= Broken seeds (%)

CS= cracked seeds (%)

PS= annual processed seeds (kg)

EED= Annual economical estimation of damage (USD)

p= price per kilogram (USD)

3 Results and discussions

3.1 Seed corn production Factory in Seed and Plant Improvement Institute (SPII)

The t-test results of evaluation indexes in SPII factory are demonstrated in Table 3.

Table 3 T-test evaluation of elevators in SPII

Evaluation index	Degree of freedom	t value	Standard deviation / Conventional elevator	Standard deviation / Z-Shape elevator
Operation deference between two types of elevators in breakage of round seeds	8	2.376*	1.274060	0.849
Operation deference between two types of elevators in breakage of medium seeds	8	4.973**	0.3843	0.281
Operation deference between two types of elevators in breakage of large seeds	8	3.724**	0.280826	0.441
Operation deference between two types of elevators in cracking of round seeds	8	4.505**	4.626	0.952
Operation deference between two types of elevators in cracking of medium seeds	8	8.134**	1.373	0.808
Operation deference between two types of elevators in cracking of large seeds	8	4.738**	2.137	1.866

Note: Significant difference at 5% level of probability*, Significant difference at 1% level of probability**.

Results of t-test indicated that applying Z-Shape elevators had considerable effects on reducing seed breakage. In line with the results, operation different between two types of elevators was significant at 1%

probability level for breakage of large and medium seeds and 5% probability level for round seeds breakage. Also, the difference between operations of two types of elevators on seed cracking was significant at 1% probability level for all categories of corn seeds. The mean comparison of seeds breakage percent in two types of elevators is depicted in Figure 3.

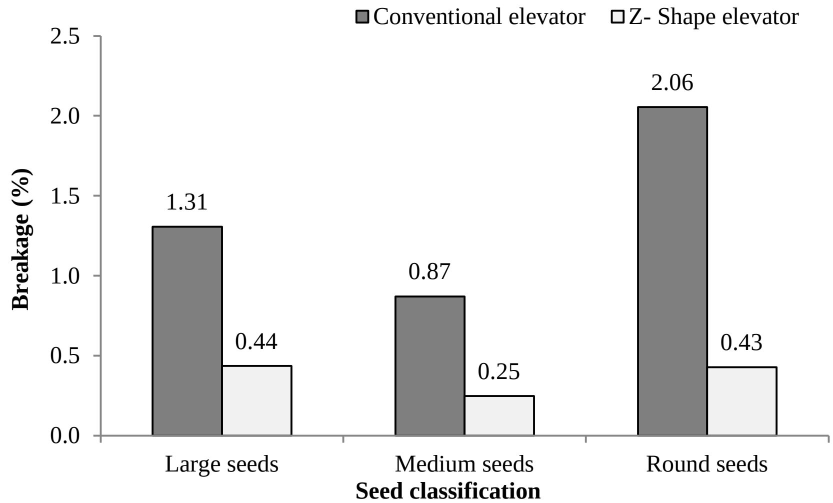

Figure 3 Difference between seed corn breakage in two types of elevator (SPII)

It was concluded that the breakage amounts of three categories of large, medium and round seeds were decreased in Z-Shape elevator so that the breakage in conventional elevator was 3 to 5 times more than that in Z-Shape elevator. Using conventional elevators caused increasing seed cracking 5 times rather than Z-Shape elevators in corn round seeds (Figure 4). Cracking in round seeds was more than another size of seeds, because the contact surface of round seeds was greater and breakage chance was more than the other seed categories. Z-Shape elevator had suitable motion and grain discharge was smooth, so the least physical damage happened during grain conveying. Conventional bucket elevators had high rotational speed (90 rpm) generally and seeds shot to outlet wall rapidly during discharging and some of them would be broken or cracked (Pliestic and Sutalo, 2001; Shahbazi, 2016).

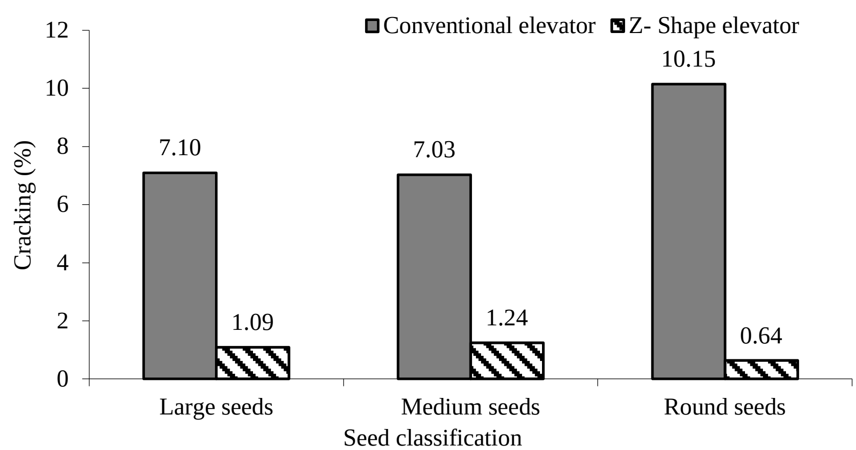

Figure 4 Difference between seed corn cracking in two types of elevators (SPII)

Loading and discharge velocity in Z-Shape elevator is less than conventional elevator and caused to decrease cracking in round, medium and large seeds to 93.6%, 82.4% and 84.7%, respectively. According to the results, it was evidenced that applying Z-Shape elevators in the seed corn processing station of Plant and Seed Improvement

Institute, increased the seed physical health 87% averagely.

3.2 Shahi seed corn production factory in Moghan Plain

The t-test results are demonstrated in Table 4.

Table 4 T-test evaluation of elevators in Shahi Company

Evaluation index	Degree of freedom	t value	Standard deviation / Conventional elevator	Standard deviation / Z-Shape elevator
Operation deference between two types of elevators in breakage of round seeds	6	2.603*	0.464	0.549
Operation deference between two types of elevators in breakage of medium seeds	6	2.594*	0.937	0.335
Operation deference between two types of elevators in breakage of large seeds	6	3.470*	0.204	0.390
Operation deference between two types of elevators in cracking of round seeds	6	7.597**	0.386	1.172
Operation deference between two types of elevators in cracking of medium seeds	6	3.325*	1.209	1.669
Operation deference between two types of elevators in cracking of large seeds	6	3.441*	1.534	0.339

Note: Significant difference at 5%*; Significant difference at 1%**

In accordance with the results, there was a significant difference at 5% between breakage operations of two types of elevators for three size classifications of seed corns. The difference in cracking operation of elevators was significant at 1% for round seeds and 5% for large and medium seeds. The results were similar to seed corn production factory in Seed and Plant Improvement Institute.

In Shahi factory, using Z-Shape elevator caused to decrease seed cracking until 60%-70% in comparison with conventional elevator (Figure 5).

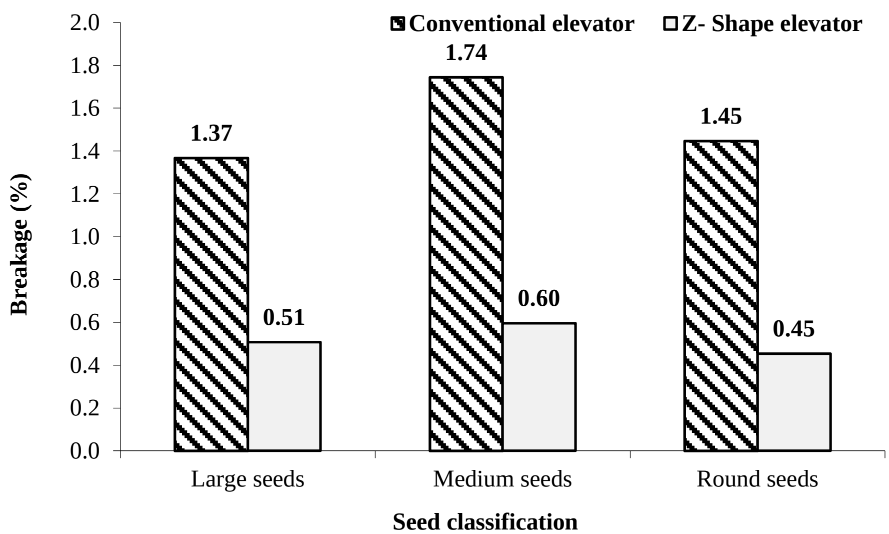

Figure 5 Difference between seed corn breakage in two types of elevators (Shahi factory)

The chance of seed cracking was increased 4-8 times in conventional elevators in comparison with Z-Shape elevators (Figure 6). This phenomenon was more obvious in round seeds so that the cracking increased to 8 times when conventional elevator was employed for handling. Applying Z-Shape elevators decreased the seed physical damages in Shahi factory in Moghan Plain as similar with factory of Seed and Plant Improvement Institute.

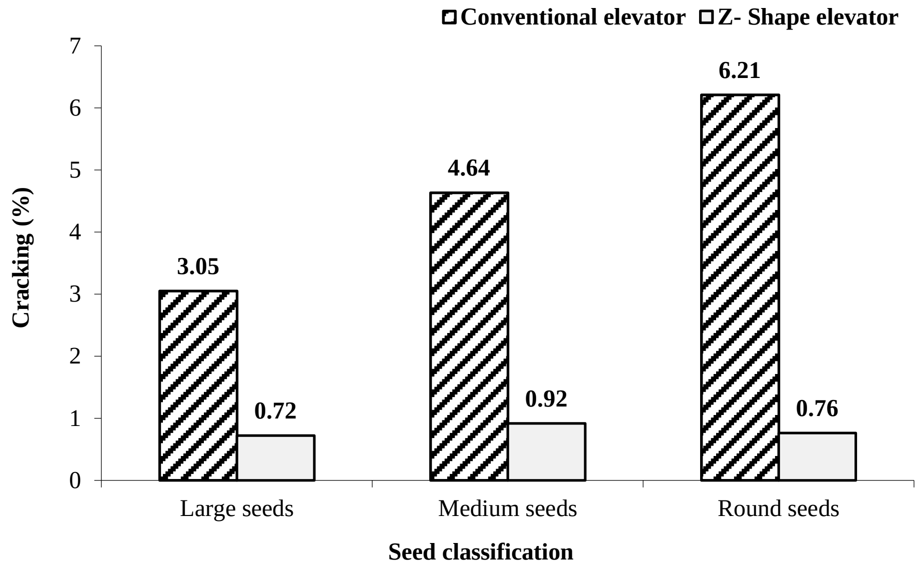

Figure 6 Difference between seed corn cracking in two types of elevator (Shahi factory)

3.3 Economic advantages of using Z-Shape elevators in Moghan Plain

According to the report of Ministry of Agriculture-Jahad, 10000 tons of hybrid seed corn produced annually in Moghan Plain. The price of seed corn is 2.87 US dollars per kilogram in Iran now. Results demonstrated 510 tons of seeds would be broken during handling by conventional elevators in seed drying stations every year. Also, the amounts of cracked seeds reached to 1830 tons in Moghan plain (Gazor and Hamidi, 2009). The summation of total damage was calculated as 6,715,800 US dollars in a year (Table 5).

Table 5 Estimation of monetary damages in Moghan Plain during employing conventional elevators

Losses	Amount (%)	Damages	
		Ton	US Dollar
Breakage	5.1	510	1,463,700
Cracking	18.3	1830	5,252,100
Total	23.4	2340	6,715,800

Employing Z-Shape elevator to convey seed corns caused to decrease damages up to 10% and reach the total damages to 2.34%. Therefore, the total property damage nearly reduced as 157,150 US dollars. In this condition, total property damage was reached to 6,558,650 US dollars.

In order to equip the factory with 10 systems of Z-Shape elevators, necessary fund was estimated as US 29760 dollars. For 10 factories in Moghan Plain, total fund was almost US 297600 dollars. This amount was nearly 5% of total property damage when conventional elevators were used to convey seeds. This expense is depreciated during 20 years of elevators shelf life.

4 Conclusion

In order to decrease seed corn damages in seed processing factory, a Z-Shape elevator was used for handling and its operation was determined and compared with a conventional elevator in two stations of Seed and Plant Improvement Institute (SPII) and Shahi factory. Results showed the breakage percentage in three size classifications of seeds was decreased in Z-Shape elevator so that breakage in conventional elevator was 3.5 to 5 times more than that in Z-Shape elevator. Using Z-Shape elevators caused to decrease seed cracking until 60%-70% in comparison with conventional elevators. The chance of seed cracking was increased 4-8 times in conventional elevators in comparison with Z-Shape elevators. Employing Z-Shape elevators to convey seed corns caused to decrease monetary damages up to 10%. The total monetary damages nearly reduced as 157,150 US dollars. By consuming 5% of this amount while conventional elevators were used to convey seeds, 10 factories can be equipped with Z-Shape elevators.

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