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Operational Characteristics of Black Carrot Harvester with Vibrating Cleaning Elevator

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ABSRACT

Operational characteristics of a black carrot harvester with vibratory cleaning elevator were determined in this research. The machine is able to harvest two ridges at a time. The harvester was operated at 0.21, 0.34 and 0.48 m s^{-1} forward speeds over a black carrot field with pulled-off ringlets and cleaned heads. Depending on forward speeds, dirtiness ratios varied between 6.75 - 18.42%, broken carrot ratios between 3.76 - 14.55%, surface wound ratios between 4.11 - 1.55%, drafts between 1203 - 1363 daN, bollard pulls between 2.48 - 6.41 kW and power take-offs shaft powers between 2.32 - 2.87 kW.

1. Introduction

Black carrots are rich in sugar, vitamin A and ceratine. Turkey and India are the largest black carrot consumers of the world. Consumption is usually as fermented beverage rather than fresh consumption.

Fermented carrot juice contains lactic acid and carrots contain average 6–10 mg 100 g^{-1} ascorbic acid (Cemeroğlu et al., 2001). Besides providing sourness to carrot juice, lactic acid also has digestive and refreshing effects, adjust the pH of digestive system and allows the body to benefit more from some minerals (Miişoğlu, 2004).

Black carrot has a high antioxidant activity and it is a potential anthocyanin pigment source. It has high antioxidant content (1750 mg kg^{-1}) and special quality parameters (Kırca et al., 2006). Anthocyanins are the most popular natural food colorings providing the carmine color to foods and commonly used as an alternative of synthetic food dyes (Bridle and Timberlake, 1997; Giusti and Wrolstad, 2003).

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Anthocyanins were proved to have threpuatic effects on vascular diseases especially on artery thickening, cancers and diabetes, nerve degenerations and some eye diseases (Kong et al. 2003; Wrolstad, 2004). There are also several anthocyanin-containing pharmaceutical products in markets

Black-carrot cultivation lands and amount of productions have been increasing recently in Konya – Ereğli region. Especially Kuzukuyusu, Beyören, Akören and Sazgeçit districts meet about 80% of black carrot production. Although reliable data is not available, it was reported that black carrot producers of the region contracted about 150 -160 thousand tons of production. Such productions correspond about 4 thousand hectares productions sites.

Although there are various researches conducted on yellow carrot harvesters, there are not any study conducted on black carrot harvesters. Özarslan, (1989) tested single-row harvester prototype by using two-pieces winged fork and single-piece finger pullers under laboratory conditions with wooden carrot models. Researcher obtained pulling ratios of 97.5, 100 and 60.53% with two-pieces winged puller at 25 cm operational depth and respectively at 0.39, 0.68 and 1.36

m s^{-1} forward speeds. Özarslan et al., (1995) developed and tested the prototypes of carrot harvesters with vibratory sieves and elevator storage. Researchers reported an operating speed 1.5- 2 km h^{-1} for vibratory sieved prototype and indicated that a worker was able to pull-off about 3-4 da land area in a single day. Tests on elevator-storage prototype revealed that a pulling depth of 25 cm was proper for a quality pull-off and 8 da land area was able to be pulled-off in a single day at 2.5 – 3 km h^{-1} operating speeds.

It was indicated in previous researches that pulling loss in sugarbeet should be around 3% (Traulsen, 1974) and pull-off and root break-off losses, head cutting quality, dirtiness ratio and surface wounds should all be taken into consideration while testing and evaluating the harvesters (Brinkmann, 1988).

Kanofojski and Karwowski, (1976) indicated that pull-off harvesters could commonly be used since segmented-type scrapers can be used over every kind of soils, scrape the ridges and scraper penetration angles may be increased up to 35°.

Hacıseferoğulları et al., (2000) determined the pull-off losses of a fork-type puller in sugarbeet as 0.36, 1.26 and 1.79% and drafts as 4414, 5277 and 6435 respectively at 0.51, 0.77 and 1.04 m s^{-1} forward speeds.

In present research region, harvested black carrots are collected by a labor force and loaded to trailers. They then transported to washing facilities, washed there and moved to concentrate facilities. In current research, operational characteristics of a puller harvester with vertical-vibratory cleaning elevator were determined.

2. Material and Method

Experiments were carried out in Kuzukuyusu Village of Ereğli, Konya. The harvester with vibratory cleaning elevator, used in this study, is a local brand and commonly used in black carrot harvest of the region. Hattat A110 4WD tractor was used in experiments.

There are two sharp-edged separator discs beside the scraper in front of the harvester hood. The general view of the machine used is shown in Figure 1. The motion taken from power take-off of the tractor is transferred to a gear box mounted over the hood and then the motion is oriented with 90° and transferred to elevator pulley located on lest side of the machine. The motion behind the machine is transferred to eccentric pulley (Figure 2).

The soil and carrots pulled-off from the ridges of two rows by the scraper are transported to cleaning elevator. Vertical vibration is provided to elevator by an eccentric mechanism and soil over the elevator is sieved through. Finally, harvested and dirtiness-sieved black carrots are left over the field. Some technical specifications for the harvester are provided in Table 1.

Figure 1
Black carrot harvester machine

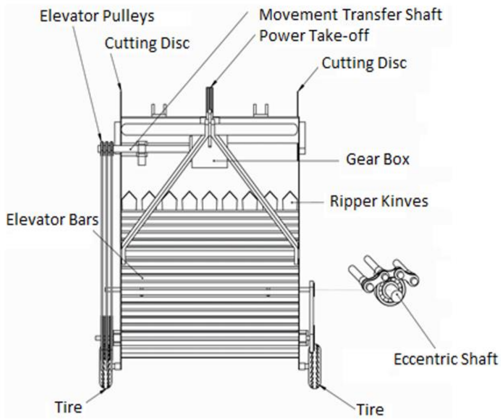

Figure 2
Schematic view of black carrot harvester with vibratory cleaning elevator

Sowing ridges are presented in Figure 3. Black carrots were sown in three rows over each ridge of experimental field with a vacuum-type pneumatic precision planter. Row spacing was 7.5 cm and on-row plant spacing was 2.5 cm. Total ridge width was 32 cm and ridge height was 20 cm.

Table 1
Specifications for the harvester tested in this study

Specifications	
Separator disc diameter	:560 mm
Separator disc thickness	:6 mm
Scraper penetration angle	:32°
Scraper cutting angle	:90°
Scraper knife length	:420 mm
Scraper knife width	:125 mm
Number of scraper knife	:9
Elevator area	:1.96 m^2
Bar diameter	:16 mm
Bar spacing	:44 mm
Number of bars	:56
Chain step	:60 mm
Eccentric dimeter	:20 mm

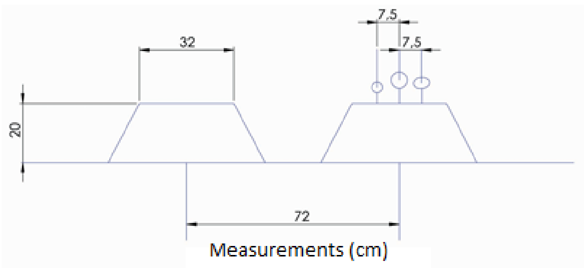

Figure 3
Sowing ridges

Experiments were conducted in randomized block design with three replications. Plot size was arranged as 1.35 x 50 m. Non-stony experimental field has a sandy-loam texture with 68% sand, 20% clay and 12% silt. Average block relative humidity was 14.89%. Experiments were implemented at 0.21, 0.34 and 0.48 m s^{-1} forward speeds, 375 min^{-1} power take-off rate and average 28 cm operational depth.

Over the experimental plots, 10 rows were randomly selected and the distance between the nearest plants along 5 m row length were measured with a steel rule. Recorded measurements were then used to create the relative ratio groups (Figure 4). Plant characteristics of black carrots are provided in Table 2.

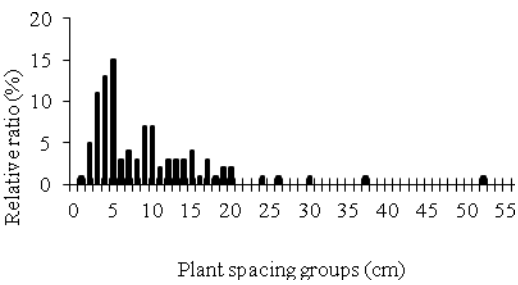

Figure 4
On-row plant distribution

Table 2
Characteristics of black carrots

Measured characteristics	Value
Type	: Black carrot
Mass	: 105.71±6.49 g
Number of plant per unit area	: 47±2.79 plant m^{-2}
Average carrot length	: 204.59± 8.05 mm
Average carrot diameter	: 41.35±2.79 mm

Before to start black carrot pull-offs, ringlets were ripped off with a hay silage machine, carrot heads were cleaned with horizontally-operating crushing machine and leaves were collected with an acrobat hay rake. Image of a ridge ready to be pulled-off with a harvester is presented in Figure 5.

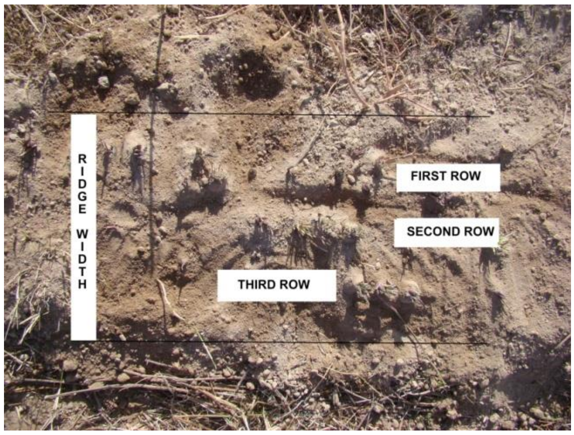

Figure 5
Top view of a ridge

Draft pins able to be fixed on three-point suspension sleeves with a capacity of 30.000 N were used to determine machine draft requirements. Signals formed over draft pins were transferred to data processor. MultiLog PRO brand portable data logger with a graphic analyzer system, data storage and adjustable data range was used for data processing.

Datum Electronics brand power take-off torque meter with a capacity of 1800 Nm was used to determine torque requirements. Torque meter signals were directly transferred to computer and saved in *xls format with special software.

Dirtiness ratio, root break-off ratio, surface wounds ratio, pull-off losses ratio were taken into consideration while testing and evaluating the harvesters operating qualities of tuber-plants (Brinkmann, 1988). A total of ten samples were taken from randomly selected 1 m^2 surface areas over the experimental plots and then samples were transported to laboratory and analyzed there.

Dirtiness ratio was determined as the ratio of the weights of residual soil particles over the harvested carrots to the weight of harvested carrots.

Pull-off losses were determined by weighting the non-harvested carrots removed by manual digging of 1 m^2 harvest area of each plot.

Broken carrot ratio was determined as the ratio of the weight of broken and cleaned carrots to the weight of harvested carrots.

To determine surface wounds, color changes over the cleaned and washed carrots of each plot were taken into consideration. Following the wash-up, wounded parts of the black carrots had darker colors as shown in Figure 6. Wound ratios were determined as the ratio of the weights of carrots with peel wounds to the weight of harvested carrots of each plot. Only slight peel-offs (surface wounds) were observed rather than deep wounds.

Figure 6

An image of black carrots with slight peel-offs

Variance analysis and LSD test were performed to determine the effects of forward operating speeds of carrot harvester on dirtiness ratio, root-break-off ratio and surface wound ratio (Düzgüneş et al., 1983).

3. Results

Dirtiness, root break-off, surface wound and pull-off loss ratios at different forward operational speeds of black carrot harvester are provided in Table 3.

Dirtiness ratios increased with increasing forward speeds. Such increases were observed as 151 and 273% corresponding to increases in forward speeds of 162 and 229%, respectively. Variance analysis revealed significant relationships between dirtiness ratios and forward speeds (F=16.97). LSD test revealed that dirtiness ratio at 0.48 m s^{-1} forward speed was different from the dirtiness ratios of the other forward speeds. Such a case may be due to constant eccentric diameter since it was not able to be enlarged.

Table 3

Harvester operational quality parameters

	Operational speed (m/s)			
Parameters	0.21	0.34	0.48	
Dirtiness ratio (%)	6.75±0.81b	10.16±2.43b	18.42±1.72a	LSD (p<0.01)=6.909
Broken carrot ratio (%)	3.76±0.36b	11.61±2.20a	14.55±0.76a	LSD (p<0.01) =5.248
Surface wound ratio (%)	4.11±0.55	3.51±1.67	1.55±0.97	-
Pull-off losses (%)	-	-	1.65±0.70	-

The broken carrot ratios also increased respectively by 309 and 387% with 162 and 229%increases in harvester forward speeds. Again, variance analysis revealed significant relationships between forward operational speeds and broken carrot ratios (F=25.43). LSD test revealed that broken carrot ratio at 0.21 m s^{-1} forward speed was different from the broken carrot ratios of the other forward speeds. In other words, the lowest ratio (3.76%) was observed at 0.21 m s^{-1} forward speed. Differences in broken carrot ratios were basically due to operation of the scraper.

Surface wound ratios of 0.21 and 0.48 m s^{-1} forward speeds varied between 1.55 - 4.11% and decreased with increasing forward speeds. Variance analysis revealed insignificant relationships between harvester forward speeds and surface wound ratios (F=2.01). The decrease in surface wound ratios with increasing forward speeds was due to shorter transport duration of the carrots over elevator at higher speeds.

With regard to pull-off losses, while there were not any pull-off losses at 0.21 and 0.34 m s^{-1} forward speeds, a pull-off loss ratio of 1.65% was observed at 0.48 m s^{-1} harvester forward speed.

Draft, bollard pull and power take-off values increased with increasing machine forward speeds (Table 4). Based on forward speeds, drafts varied between 1203 - 1363 daN, bollard pulls between 2.48 - 6.41 kW and power take-offs between 2.32 - 2.87 kW.

4. Conclusion

Operational characteristics of a black carrot harvester were determined in present study. In general, while increasing dirtiness ratios and broken carrot ratios were observed with increasing forward speeds, a decrease was observed in surface wound ratios with increasing speeds. Such results may indicate that the harvester should be operated at 0.20 m s^{-1} forward speed. Under these circumstances, a work success of 0.85 da h^{-1} was reached.

Table 4
Draft, bollard pull and power take-off values of harvester

	Operational speed (m s^{-1})		
	0.21	0.34	0.48
Draft (daN)	1203	1280	1363
Bollard pull (kW)	2.48	4.26	6.41
Power take-off (kW)	2.32	2.65	2.87

Following conclusions were also drawn from the experiments carried out in current study;

-Deeper scraper penetration may be obtained by providing vertical vibrations,

-Transitional parts of sieving apparatus, edges and elevator bars may be lined with plastic material and surface wounds may be prevented in this way,

-Stroke of the eccentric providing vibrational movements to elevator may be increased, an adjustable fashion may be provided and cleaning ratio may be improved in this way,

-A belt conveyor may be added to harvester to transfer the carrots to trailer. In this way, labor requirement to collect the harvested carrots may be eliminated,

-Considering all the above mentioned recommendations, cost-effective local brands may be used instead of highly expensive imported harvesters.

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