

Article

Not peer-reviewed version

Engineering Assessment of the Physical Properties of Carrot Seeds for Precision Seeders

[Yanchenko Elena](#) *

Posted Date: 14 July 2025

doi: 10.20944/preprints202507.1122.v1

Keywords: SEED; Flowability; SPHERICITY; CARROTS; SEEDS; BIOMETRIC INDICATORS



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This open access article is published under a Creative Commons CC BY 4.0 license, which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Article

Engineering Assessment of the Physical Properties of Carrot Seeds for Precision Seeders

Yanchenko Elena

Federal State Budgetary Scientific Institution "Federal Scientific Vegetable Center"; elena_0881@mail.ru

Abstract

The key to increasing carrot yield is to produce a quick and uniform harvest. Rapid early leaf growth and development of a strong root system will help minimize variability in morphological traits and increase carrot yield. Carrot seeds are small and irregular in shape. To achieve optimal density, pre-sowing seed treatment followed by single-seed sowing is necessary. The purpose of this study is to determine some physical properties of carrot seeds, namely size, sphericity, surface area, bulk density, true density, porosity, angle of repose and static coefficient of friction before and after seed grinding on the performance of various seeder units. The study is based on a laboratory experiment with the carrot variety NIIOH-336. The original carrot seeds with a moisture content of 9% had an average length of 4.19 mm, width - 1.81 mm, thickness - 1.09 mm. After grinding, the values are fixed at 3.28 mm, 1.75 mm and 1.06 mm, respectively. Grinding led to an increase in flowability, bulk density from 359 to 416 kg/m³, true density - from 1024 to 1086 kg/m³, seed roundness - from 0.45 to 0.63. The minimum unevenness of seeding between dispensers (3.3-3.4%) of seed fractions of 1.5-2.0 mm and 2.0-2.5 mm was established when sowing with a SONP-2.8 pneumatic seeder (mounted pneumatic vegetable seeder with working width 2.8 m). Knowledge of the physical properties of seeds is necessary when harvesting, processing, storing, encrusting, panning, priming, as well as sowing with precision seeders. Various types of cleaning, sorting and separating equipment can be designed based on the physical properties of the seeds.

Keywords: seed; flowability; sphericity; carrots; seeds; biometric indicators

1. Introduction

Plant materials play an important role in the human diet, and carrot roots (*Daucus carota* L., 1753) are one of the most commonly consumed vegetables. The year-round availability of carrots is due to their high nutritional value and long shelf life. Root vegetables are excellent raw materials for the processing industry. They are used for the production of juices, frozen and dehydrated foods, and canned carrots [1,2]. The quality of carrot roots is determined by many factors, including variety, environmental conditions, growing method and storage technology [3–6].

Modern carrot production technologies face new requirements for pre-sowing seed treatment. Many vegetable seeds are small, light, and irregular in shape; therefore, they are difficult to sow [7]. There are certain limitations associated with the production, processing and effective use of small seeds. Carrot seeds are small in size and difficult to process for sowing. A large amount of expensive seed can be wasted due to uneven seed placement, thinning, damage by the seed metering mechanism during sowing, and damage by birds. The study of the engineering properties of carrot seeds is of utmost importance for sowing. In recent years, the physical properties of seeds of various crops, such as onions [8], coriander [9], millet [10], quinoa [11], almonds [12], corn [13], lentils [14], seed have been studied. [15]. Biometric indicators of seeds play an important role during harvesting, processing, storage, as well as during encrusting, pelleting, and priming of seeds, in particular, when sowing with precision seeders. Fast and uniform germination of graduated seeds is an important prerequisite for increasing yield and product quality, especially for direct-seeded vegetable crops such as carrots.

2. Materials and Methods

The purpose of the study is to improve the biometric indicators of carrot seeds to increase the accuracy of sowing and the high-quality operation of sowing devices of the seeder.

To achieve this goal, the following tasks are set:

- give an engineering assessment of the physical properties before and after grinding carrot seeds;
- determine the influence of the size of ground carrot seeds on the quality of operation of various sowing devices of the seeder.

The size and shape of fifty randomly selected seeds were measured using an Olympus BX 61 microscope (Japan).

The geometric mean diameter (D_p) of seeds was calculated using the formula (1) [16]:

$$D_p = (L \times W \times T)^{1/3} \quad (1),$$

Where L - length, mm; W - width, mm; T - thickness, mm.

The arithmetic mean diameter (D_a) was determined by the formula (2):

$$D_a = \frac{L+W+T}{3} \quad (2).$$

Sphericity (Ψ) was calculated using the formula (3):

$$\Psi = \frac{(LWT)^{1/3}}{L} \quad (3).$$

Roundness was taken into account using the formula (4):

$$\text{Roundness} = (W/L + T/L + T/W) / 3 \quad (4).$$

The surface area (S) of the achene was measured in mm², which was found using the following relationship (5) [17].

$$S = \pi D_p^2 \quad (5).$$

The volume of seeds and their density were determined by the liquid displacement method [16]. Toluene (C₇H₈) was used instead of water, it is less absorbed by the seeds, and its surface tension is low, it fills even small depressions in the seed and its dissolution ability is low [18].

True density was determined using the following equation (6):

$$\rho_t = (M / \rho_b), \quad (6),$$

Where: M - sample mass (g), ρ_b - bulk density (cm³).

Porosity (ε) was measured using the relation (7) [19]:

$$\varepsilon = 100 (1 - \rho_b / \rho_t) \quad (7),$$

Where: ε - porosity (%), ρ_b - bulk density (g/cm³), ρ_t - true density (g/cm³).

The coefficient of static friction was calculated using the formula (8) [20]:

$$\mu = \text{tg } \alpha', \quad (8),$$

Where: μ - coefficient of static friction, $\text{tg } \alpha'$ - tangent angle of inclination of the plane at the moment the seeds begin to move relative to the inclined plane.

To determine the coefficient of static friction of seeds, a wooden surface was used.

The weight of 1000 seeds were calculated manually and then weighed on an electronic scale.

The angle of repose was determined by measuring the height and diameter of the seed mound [21]. To determine the angle of repose of carrot seeds, a plastic cylinder (inner diameter 70 mm and height 270 mm) was held vertically on a horizontal wooden surface and filled with the sample. Tapping during filling was done to obtain uniform density and minimize wall effect, if any. The cylinder was slowly raised up so that all the material could slide freely, forming a mound. The mound height (H) and mound diameter (D) were measured using a measuring scale, and the angle of repose (φ) of the seeds was calculated using Eq (9) [22,23].

$$\varphi = \text{tg}^{-1} (2H / D) \quad (9).$$

The initial seed moisture was 9%. Carrot seeds were ground using a ShSS-0.5 grinding machine (Russian Federation). In it, the seeds pass between metal fingers on a rotating auger and stationary metal fingers extended from the wall. The quality and speed of grinding depend on the rotation speed of the auger, the angle of the working chamber and the degree of openness of the outlet valve of the working chamber.

The seeds were calibrated on a wind screen machine SM-0.15 with the installation of a lower sieve with round cells $\varnothing 1.5$ mm, and an upper sieve with $\varnothing 2.0$ mm

3. Results

The separation of seeds according to shape, size and density occurs during the process of part-time processing after harvesting. Length, width and thickness characterize the linear dimensions of the seeds. The initial batch of carrot seeds of the NIIOH-336 variety had the following linear parameters: length - 2.64-4.75 mm, width - 1.13-2.21 mm, thickness - 0.63-1.72 mm. After grinding the seeds, these values were 1.58-3.85 mm, 1.05-2.08 mm and 0.61-1.61 mm, respectively (Table 1).

Table 1. Size of carrot seeds of the NIIOH-336 variety before and after grinding (n=50 pcs.).

Parameter	Meaning	
	before grinding	after grinding
Length, mm	range	2,64-4,75
	mean	4,19
	standard deviation	0,78
Width, mm	range	1,13-2,21
	mean	1,81
	standard deviation	0,35
Thickness, mm	range	0,63-1,72
	mean	1,09
	standard deviation	0,36

Source: [Compiled by the authors].

The choice of technological solutions and equipment for sowing, harvesting, threshing, drying, sorting and other processes depends on the shape, size and surface features that determine friction, flowability, aerodynamics and other physical properties of seeds. In the study, the geometric mean diameter of carrot seeds varied from 1.27 to 2.65 mm before grinding and from 1.16 to 2.56 mm after grinding. The average value of seed sphericity was 0.45 and 0.63, respectively (Table 2).

Table 2. Average geometric diameter and sphericity of carrot seeds of the NIIOX-336 variety before and after grinding (n=50 pcs.).

Parameter	Meaning	
	before grinding	after grinding
Average geometric diameter, mm	range	1,27-2,65
	mean	2,01
	standard deviation	0,42
Sphericity	range	0,39-0,57
	mean	0,45
	standard deviation	0,05

Source: [Compiled by the authors].

The angle of repose is one of the indicators of seed flowability: the smaller the angle, the higher the seed flowability. After grinding the seeds, the flowability increased significantly and the angle of repose decreased from 42.11 to 40.99°. Grinding led to an increase in bulk density of seeds from 359 to 416 kg/m³, true density - from 1024 to 1086 kg/m³, roundness - from 0.45 to 0.63. After grinding, the weight of 1000 seeds decreased from 1.36 to 1.31 g, the coefficient of static friction decreased from 0.88 to 0.87 (Table 3).

Table 3. Physical properties of carrot seeds of the NIIOX-336 variety before and after grinding (n=50 pcs.).

Parameter	Meaning	
	before grinding	after grinding
Weight of 1000 seeds, g	1,36	1,31
Angle of repose (degree)	42,11	40,99
Embankment density (kg/m ³)	359,0	416,0
True density (kg/m ³)	1024	1086
Porosity (%)	65	62
Roundness	0,45	0,63
Static friction coefficient	0,88	0,87

Source: [Compiled by the authors].

The germination rate of carrot seeds when using precision seeders should be at least 85%, and according to GOST 32592-2013 "Sowing qualities of seeds of vegetable and melon crops" [24] - at least 55%. Seeds should not contain various impurities, should be equal in size (calibrated), and have good flowability.

In our studies, the mass of dust particles formed during grinding on ShSS-0.5 ranged from 1.5 to 3.0% of the initial mass of seeds. After grinding, with a decrease in the angle of repose, the bulk density of the seeds increased, which is associated with the absence of spines, bristles, villi, outgrowths and other protruding irregularities on their surface.

When grinding carrot seeds in 1 hour of pure time, the average productivity of ShSS-0.5 is 400 kg. With a heap weight of at least 4-5 kg, satisfactory quality of ground seeds is achieved.

Dust particles formed during grinding are largely removed from the heap of seeds when unloaded by the air flow of the "Cyclone" system, where they settle. However, some small particles remain in the heap of seeds. To remove such particles, it is necessary to refine the seeds on air sieve machines. For the best operation of the sowing unit, the seeds must be calibrated. This allows you to adjust the seeding units for more accurate seeding. Aligned seeds by size allow you to better adjust the "scrapers" of the sowing devices of a pneumatic precision seeder. At the same time, seed calibration affects the quality of seeding not only of pneumatic sowing devices, but also of alternative electromechanical sowing devices of the Klen seeder.

When using air screen machines configured for fractionation mode, it is possible to separate seeds into fractions based on size and aerodynamic properties. In our studies, seed calibration was carried out on a wind sieve machine SM-0.15 with the installation of a lower sieve with round cells Ø1.5 mm, and an upper sieve with Ø2.0 mm. The fraction less than Ø1.5 mm was sent to waste. The seed fraction coming off the lower sieve was more than 1.5-2.0 mm, and the amount coming off the upper sieve was 2.0-2.5 mm. Seeds larger than 2.5 mm and large debris were removed on a preliminary sieve with round cells Ø2.5 mm. When replacing the upper sieve with a sieve with round cells Ø2.5 mm, the flow from the lower sieve consisted of a fraction with a seed size of 1.5 to 2.5 mm.

Calibration of ground seeds significantly affects the uniformity and stability of the operation of sowing devices of various types of seeders. Minimal unevenness of seeding between devices (3.3-3.4%) of seed fractions of 1.5-2.0 mm and 2.0-2.5 mm was revealed when sowing with a SONP-2.8 pneumatic seeder (mounted pneumatic vegetable seeder with working width 2.8 m), which is significantly lower than when sowing with a Klen seeder (Table 4).

Table 4. Influence of the size of ground carrot seeds of the NIIOX-336 variety on the quality of operation of various sowing devices.

Planter	Seed fraction, mm	Uneven seeding between devices		Instability of total seeding	
		± kg/ha	%	± kg/ha	%
Klen	1,5-2,5	0,132	8,8	0,096	6,4
	1,5-2,0	0,071	4,7	0,033	2,2
	2,0-2,5	0,073	4,7	0,034	2,3

	1,5-2,5	0,044	6,7	0,033	9,9
SONP-2,8	1,5-2,0	0,022	3,4	0,015	4,6
	2,0-2,5	0,021	3,3	0,014	4,4

In general, seed engineering properties play an important role in the design of planter metering units. These findings may provide valuable information for the design of various seeding units.

4. Discussion

The physical properties of carrot seeds such as size, shape, 1000 seed weight and angle of repose, bulk density and coefficient of static friction are important from an engineering point of view. In our studies, the average geometric diameter of seeds before grinding was 1.27-2.65 mm, after grinding - 1.16-2.56 mm. At the same time, the angle of repose was at 42.11 and 40.99°, and the porosity was 85 and 82%, respectively. In previous studies, the average geometric diameter of carrot seeds was 2.03-2.70 mm, the average values of the angle of repose were 28.00-32.79°, and the porosity was 64.96% [25]. Maximum yield is ensured by seeds that have an optimal linear size ratio (L:W:T) for each plant species and even variety [26].

At the end of seed grinding, the flowability of the seeds increased significantly and the angle of repose decreased from 42.11 to 40.99°. After grinding, the mass of 1000 seeds decreased from 1.36 to 1.31 g, and the coefficient of static friction decreased from 0.88 to 0.87. Grinding led to an increase in bulk density of seeds from 359 to 416 kg/m³, true density - from 1024 to 1086 kg/m³, roundness - from 0.45 to 0.63.

It is known that moisture content has a significant effect on the physical properties of seeds. In early studies, bulk density increased as carrot seed moisture content decreased. At the same time, the sphericity decreased with increasing humidity. True density and porosity decreased with decreasing seed moisture content. All other technical characteristics such as 1000 seed weight, surface area, arithmetic mean diameter, geometric mean diameter and angle of repose increased with increasing moisture content. The coefficient of friction decreased with increasing moisture content on four different surfaces: wood, mild steel, aluminum and galvanized iron [27]. Similar results were obtained on fennel seeds [28].

Thus, isolating seeds from the general heap according to certain parameters will increase the yield of carrot root crops due to more uniform shoots and reduce the seeding rate.

5. Conclusion

The study of the physical properties of agricultural seeds has been the subject of criticism and debate for many years and has attracted the attention of many researchers. The physical properties of seeds are the most important parameters when designing systems for sorting, processing, storage, packaging, as well as incrustation, pelleting, seed priming, and sowing with precision seeders. Carrot seeds are very small in size and irregular in shape, making sowing difficult.

The linear parameters of the initial carrot seeds of the NIOH-336 variety had on average the following values: length - 4.19 mm, width - 1.81 mm, thickness - 1.09 mm. After grinding, these values are fixed at 3.28 mm, 1.75 mm and 1.06 mm, respectively. Grinding led to an increase in flowability, bulk density from 359 to 416 kg/m³, true density - from 1024 to 1086 kg/m³, seed roundness - from 0.45 to 0.63. The minimum unevenness of seeding between dispensers (3.3-3.4%) of seed fractions of 1.5-2.0 mm and 2.0-2.5 mm when sowing with a SONP-2.8 pneumatic seeder was established.

The results of this research can be applied to the design and optimization of technological equipment, as well as for transportation, sorting, packaging, storage, encrusting, pelleting, seed priming, and sowing with precision seeders. In addition, these parameters are useful in determining the efficiency of machines and operations, assessing the quality of the final product.

References

1. Ziarati P and Arbabi-Bidgoli S 2014 Investigation of cooking method on nitrate and nitrite contents in crops and vegetables and assess the associated health risk. *Int. J. Plant Anim. Environ. Sci.*, **4**, 46–52.
2. Borisov V A, Yanchenko E V, Yanchenko A V, Gasparyan Sh V, Maslovsky S A, Zamyatina M E and Karpova M A 2019 Changes in the biochemical composition of carrots during the manufacture of quick-frozen products. *Izvestia FSCO* 1 49-54.
3. Pobereźny J, Szczepanek M, Wszelaczyńska E and Prus P 2020 The Quality of Carrot after Field Biostimulant Application and after Storage. *Sustainability*, **12(4)** 1386.
4. Szczepanek M, Siwik-Ziomek A 2019 P and K accumulation by rapeseed as affected by biostimulant under different NPK and S fertilization doses. *Agronomy*, **9**, 477.
5. Szeląg-Sikora A, Sikora J, Niemiec M, Gródek-Szostak Z, Kapusta-Duch J, Kuboń M, Komorowska M and Karcz J 2019 Impact of Integrated and Conventional Plant Production on Selected Soil Parameters in Carrot Production. *Sustainability*, **11(20)** 5612.
6. Wszelaczyńska E, Szczepanek M, Pobereźny J and Kazula M 2019 Effect of biostimulant application and long-term storage on the nutritional value of carrot. *Hortic. Bras.* **37** 451–457.
7. Tuna D and Ahmet Z 2009 Improving the traditional sesame seed planting with seed pelleting. *African Journal of Biotechnology* **8** 6120–6126.
8. Chhina R S and Sharma A D 2011 Studies on physical properties of onion seeds (*Allium cepa* L.). *Progressive Horticulture* **43(1)** 76–80.
9. Coskuner Y and Karababa E 2007 Physical properties of coriander seeds (*Coriandrum sativum* L.). *Journal of Food Engineering* **80(2)** 408–416.
10. Baryeh E A 2002 Physical properties of millet. *Journal of Food Engineering* **51** 39–46.
11. Vilche C, Gely M and Santalla E 2003 Physical properties of quinoa seeds. *Biosystems Engineering* **86(1)** 59–65.
12. Aydin C 2003 Physical properties of almond nut and kernel. *Journal of Food Engineering* **60** 315–320.
13. Inderpal Singh Brar, Anoop Kumar Dixit, Rohinish Khurana and Anand Gautam 2017 Studies on Physical Properties of Maize (*Zea mays* L.) Seeds. *Int. J. Curr. Microbiol. App. Sci.* **6(10)** 963- 970
14. Oroian M 2017 The temperature hydration kinetics of *Lens culinaris*. *Journal of the Saudi Society of Agricultural Sciences* **16(3)** 250-256.
15. Gojiya D K, Dobariya U D, Pandya P A and Gojiya K M 2020 Studies on Physical Properties of Peanut Seed. *Acta Scientific Agriculture* **4(3)** 01-05.
16. Mohsenin N N 1970 Physical Properties of plant and animal materials. Gordon and Breach Science Publishers, New York.
17. Altuntases E O, Zgo Z E and Tas-er O F 2005 Some physical properties of fenugreek (*Trigonella foenum-graceum* L.) seeds. *J. Food Eng.* **71** 37-43.
18. Ogut H 1998 Some physical properties of white lupin. *Journal of Agricultural Engineering Research* **69** 237–277.
19. Vursavus K, Kelebek H and Selli S 2006 A study on some chemical and physico-mechanic properties of three sweet cherry varieties (*Prunus avium* L.) in Turkey. *J. Food Eng.* **74** 568-575.
20. Dutta S K, Nema V K and Bhardwaj R K 1988 Physical properties of grain. *J. Agric. Eng. Res.* **39** 259-268.
21. Kaleemullah S and Gunasekar J J 2002 Moisture dependent physical properties of areca nut kernels. *Biosystem Engineering* **82(3)** 331–338.
22. Bart-Plange A and Baryeh E A 2003 The physical properties of category B cocoa beans. *Journal of Food Engineering* **60** 219–227.
23. Mohsenin N N 1980 Structure, physical characteristics and mechanical properties of plant and animal materials. Gordon and Breach Press, New York.
24. GOST 32592-2013 Sowing qualities of vegetable and melon seeds
25. Gautam A, Khurana R, Manes G S and Dixit A K 2016 Studies on Engineering Properties of Pelleted Carrot (*Daucus carota* L.) Seeds. *International Journal of Bio-resource and Stress Management* **7(5)**1044-1048.
26. Makrushin NM, Makrushina EM, Shabanov RY. Seed production. – Simferopol: IT “Arial”. 2012. 564 p.
27. Devi T B and Mani Indra 2017 Study of engineering properties of vegetable seeds for design of seed dryer. *Indian Journal of Agricultural Sciences* **87** 1307-1313.

28. Shafiee S, Motlagh A M and Minaei S 2010 Moisture dependent physical properties of fennel seeds. *Afr. J. Agric. Res.* **5(17)** 2315-2320.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.