



Physico-mechanical and Bio-properties of medicinal and aromatic seeds affecting design and operation the mechanical parts

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Abstract

For the importance of medicinal and aromatic seeds which were require the keep quality and germination efficiency to rich the production and export. The create data bank for the medicinal and aromatic seeds properties is important to achieve the research aim by reduce time, effort and cost at design and development the agricultural machines and equipment. The experimental studied include the seven varieties of medicinal and aromatic seeds types and four levels of soaking time. The measurements and determination of the seed's properties were done on the dry seeds (before soaking) "main dimensions, frequency, volume, geometric and arithmetic mean diameters, surface area, roundness, bulk density, 1000 seeds mass, terminal velocity and moisture content" and the effective properties, of soaking seeds moisture contents, at coefficient of friction and repose angle. The results concluded that the linear models have a perfect to describe the relation between the each of bulk density, volume and roundness with the main dimensions of different seeds under study. The study recommends the possibility of applying the resulting mathematical models to obtain results that help in designing the appropriate size and capacity of tanks. Appropriate angles and manufacturing materials can also be selected according to the moisture content of the seeds, the coefficient of friction, and the stacking angle in agricultural machinery, transport, handling, and storage equipment.

Keywords: Data bank, models, soaking time, terminal velocity, repose angle

Introduction

With the emergence of many problems for traditional agricultural systems, such as climate change, water scarcity, shrinking agricultural land and the spread of epidemics and diseases in the both of soil and seeds. At innovative methods must be adopted to solute these problems. With technological development and the move towards smart, sustainable agricultural systems, it is imperative to provide an integrated information-bank on agricultural-inputs. This saves time, effort and money during the design and development of agricultural equipment (Benamar, *et al.*, 2025; Du, *et al.*, 2023; Sun, *et al.*, 2022; Gao, *et al.*, 2021 and Wang, *et al.*, 2020) [4, 12, 14, 33, 35]. The most important of the agriculture production inputs are seeds. The seeds are widely varying in properties, which require mechanical specifications appropriate for each type. These mechanical components are some parts in; agricultural machinery, transportation and handling; both agricultural systems; traditional in soil and soilless cultivation (alternative soil - hydroponic - aeroponic).

The use of medicinal and aromatic plants in the agri-food and medical fields has emerged as a sustainable solution permitting to overcoming of adverse effects related to synthetic food additives and chemical medicines (García, *et al.*, 2022, Benkhaira, *et al.*, 2023, Benamar, *et al.*, 2023 and 2025 and Zamani, *et al.*, 2025) [3, 6, 15, 37]. Ethnobotanical studies play an important role in the discovery of medicinal and aromatic plants used by different populations for their healing potential (Benamar, *et al.*, 2024 and Bhatt, *et al.*, 2025) [5, 7]. Certainly, some studies open the way for researchers to utilize the documented ethnobotanical data for the study of the biological activities of the mentioned medicinal and aromatic plants (Chraibi, *et al.*, 2016; Benkhaira, *et al.*, 2023; Balkrishna, *et al.*, 2024 and Rastogi, *et al.*, 2024) [2, 6, 11, 30]. In order to exploit their activities, for sustainable practical applications, that including the use of

plants extracts, essential oils or isolated molecules, as green compounds in different fields such as the food industry, medical, and agricultural sectors (Nakra, *et al.*, 2025) [26].

Pal, *et al.* (2023) [27] investigated that coriander crop physical, aerodynamic and frictional property seeds were determined in order to decide parameters for the purpose of designing and performance evaluation of a thresher to threshing coriander. Razavi, *at al.* (2009) [31] found that the variation of moisture content effects of the seed properties as length, diameter, geometric mean diameter, sphericity and thousand seed mass. Also, Razavi, *at al.* (2009) [31] and Yurtlu, *et al.* (2010) [36] said that, the friction coefficient and angles of repose varied by the increase of the seed's moisture contents. They also signed that the physical properties of coriander seeds have been evaluated as a function of seed moisture content, varying from 7.95 to 15.24% (db). In the moisture range, seed length decreased linearly from 4.21 to 4.06 mm, and width, thickness, arithmetic mean diameter, and geometric mean diameter increased linearly from 3.07 to 3.2 mm, 2.35 to 2.49 mm, 3.21 to 3.25 mm and 2.13 mm, respectively with increase in moisture content. The roundness, seed volume, and seed surface area increased from 0.74 to 0.78, 12.54 to 13.04 mm³, and 14.21 to 14.34 mm², respectively at the above moisture range. One thousand seed mass increased linearly from 7.10 to 9.21 g. The true and bulk density decreased nonlinearly with moisture content from 355.43 to 343.01 kg/m³ and 227.89 to 217.23 kg/m³. Also, porosity values of coriander seeds increased nonlinearly from 35.81 to 36.62 %. The static coefficient of friction increased nonlinearly from 0.62 to 0.82 with increase in moisture content. The angle of repose increased linearly from 31.890 to 36.100° with the increase of moisture content. Ghazy *et al.* (2021) [16] found the relation relationship between the friction coefficient and angle of repose with the hopper tilt angle. On the other side, Putri (2024) [28] and Mutia and Diyanti

(2022) [25] cleared that the soaking of shallots seeds of about 30 minutes in warm water 35°C or 24 hours in plain water, had a significant effect on bio-properties as rapidly germination, and the plant morphology as height, leaves number and fresh and dry masses, compared to non-soaking. That effects due to the significant interaction that affects the percentage of germination. Rajani Bhat, *et al.* (2020) [29] conducted that the maximum shoot and root lengths, plant height, fresh and dry masses of the seedling, and seedling vigour index was recorded at soaking in water of about 30 min.

For that, the aim of the research is providing a data bank for the physico-mechanic and bio-properties of some medicinal and aromatic plant seeds that are related to the design of agricultural equipment. These data can use at design, select materials and determine the dimensions and angles of machine parts as hoppers, tanks, belts, tubes, pneumatic discs, different packaging.

Materials and Methods

The experiments tests were done in agriculture engineering research institute at July 2025. The tests include some of physical, mechanical and aerodynamic properties of seven varieties of medicinal and aromatic seeds at four levels of soaking time. The measurements cared out, calculated and evaluations, in three replicates for each, which the properties can describe as follow:

- Main dimensions were measured using the digital venire caliper with the accuracy of ± 0.05 mm. The length, width and thickness or length and diameters were measured of 100 seeds for each type of medicinal and aromatic seeds under study.
- The main physical properties were calculated using the main dimensions of seeds by the formulas described by Mohsenin (1986) [24]; Fawal, *et al.* (2008) [13] and Pal, *et al.* (2023) [27] as follow:

Then, the frequency (F) may be calculated from the following equation:

$$F = \frac{S}{B}$$

Where

S = N₀ of seed in limit dimensions, mm

B = N₀ of 100 seeds

- Seeds geometric mean diameters "GD"

$$GD = (L \times W \times T)^{1/3}$$

- Seeds arithmetic mean diameter "AD"

$$AD = (L + W + T) / 3$$

- Seeds surface area "A_{fs}"

$$A_{fs} = 2 \pi (L \times W)$$

- Roundness of seeds "Q," according the seeds shapes it can use the following formulas:

$$Q = ((L \times W \times T)^{0.33}) / L \times 100$$

or

$$Q = (d / L) \times 100$$

Where: L is the length; W is the width; T is the thickness, and d is the diameter, mm.

- The bulk density "BD" was determine by mass "M" the seeds volume "V" which measured by using the 50 ml graduated cylinder.

$$BD = \frac{M}{V}$$

- The 1000 seeds mass were account and weight using the digital balance has the accuracy of ± 0.01 .
- The repose angle measured as the angle construct at the conical shape of the seeds
- Terminal velocity: determined using the device constructed by (Fawal, *et al.*, 2008) [13] and the anemometer device to measure the air speed and the following formula used to calculate the air velocity at the average maximum high of seeds:

$$V = \frac{Q_a}{A}$$

Where: V is air velocity, m/s, A is cross-section aria of the vertical tube, m², and Q_a is the air discharge, m³/s.

- Coefficient of friction of seeds was determined using digital inclined instrument by iron sheet galvanized surface.
- Moisture content determine by oven method.

The seeds were buying from the seed sales outlets at the Agricultural Research Center, Egypt at 2025. The studied variables include the seven varieties of seeds (fennel, anise, basil, black caiman, roselle, coriander and caraway) and four levels of seeds soaking time of 0.0, 30.0, 45.0 and 60.0 min. The all seeds properties were determined before soaking in water. Thus, the seeds moisture contents were determined at dry (before soaking) and after each soaking time. While the both of coefficient of friction and repose angle were determined before and after end soaking time (60.0 min). The experimental design is the Completely Randomized Design in three replicates. The statistical analysis of frequency, standard deviation, mathematical and statistical models of the seeds properties under study were determine.

Results and Discussion

1. The main dimensions frequency for the medicinal and aromatic seeds

The basic dimensional information refers to some mechanical dimensions such as the holes of vacuum planting machines, the appropriate diameters of which are expressed as approximately ((0.64 – 0.66) * average diameter) (Ismail, 2008A and 2008B; Ismail, *et al.*, 2009; Tawfik, 2014 and Li *et al.*, 2023) [19, 20, 21, 23, 34]. It is also useful when determining the appropriate planting depth (Kimmelshue *et al.*, 2022) [22], which should be about 1.5 times the greater value (Srivastava, 1995 and Ismail, *et al.*, 2009) [21, 32]. While this information provides the appropriate diameters of the sieve holes used in seed grading operations, which determine the price and quality of the seeds, and in the case of using them as seeds, the grading process ensures a constant growth rate for the plants, which means a uniform time for crop maturity. This study shows that, the frequency of the main dimension of medicinal and aromatic seeds, fennel, anise, basil, black caiman, roselle, coriander and caraway were illustrated in Fig 1. The highest frequency of the seeds dimension were; 27.78 and 33.33 respectively at seed length ranged from 5.93 to 6.56 mm and seed diameter ranged from 1.23 to 1.42 mm for fennel seeds; 31.58 and

26.32 respectively at seed length ranged from 5.45 to 5.79 mm and seed diameter ranged from 0.86 to 1.04 and 1.22 to 1.40 mm for anise seeds; 32.00 and 40.00 respectively at seed length ranged from 1.87 to 1.99 mm and seed diameter ranged from 0.88 to 0.96 mm for basil seeds; 33.33 and 37.50 respectively at seed thickness ranged from 0.79 to 1.09 mm and seed diameter ranged from 2.31 to 2.52 mm for black caiman seeds; 44.44, 55.56 and 27.78 respectively

at seed thickness ranged from 2.097 to 2.267 mm, seed width ranged from 4.03 to 4.46 mm and seed length ranged from 5.49 to 5.71 mm for roselle seeds; 38.89 and 33.33 respectively at seed diameter ranged from 3.14 to 3.42 mm and seed length ranged from 3.92 to 4.13 mm for coriander seeds; and 28.00 and 44.00 respectively at seed length ranged from 1.03 to 1.13 mm and seed diameter ranged from 3.02 to 3.71 mm for caraway seeds.

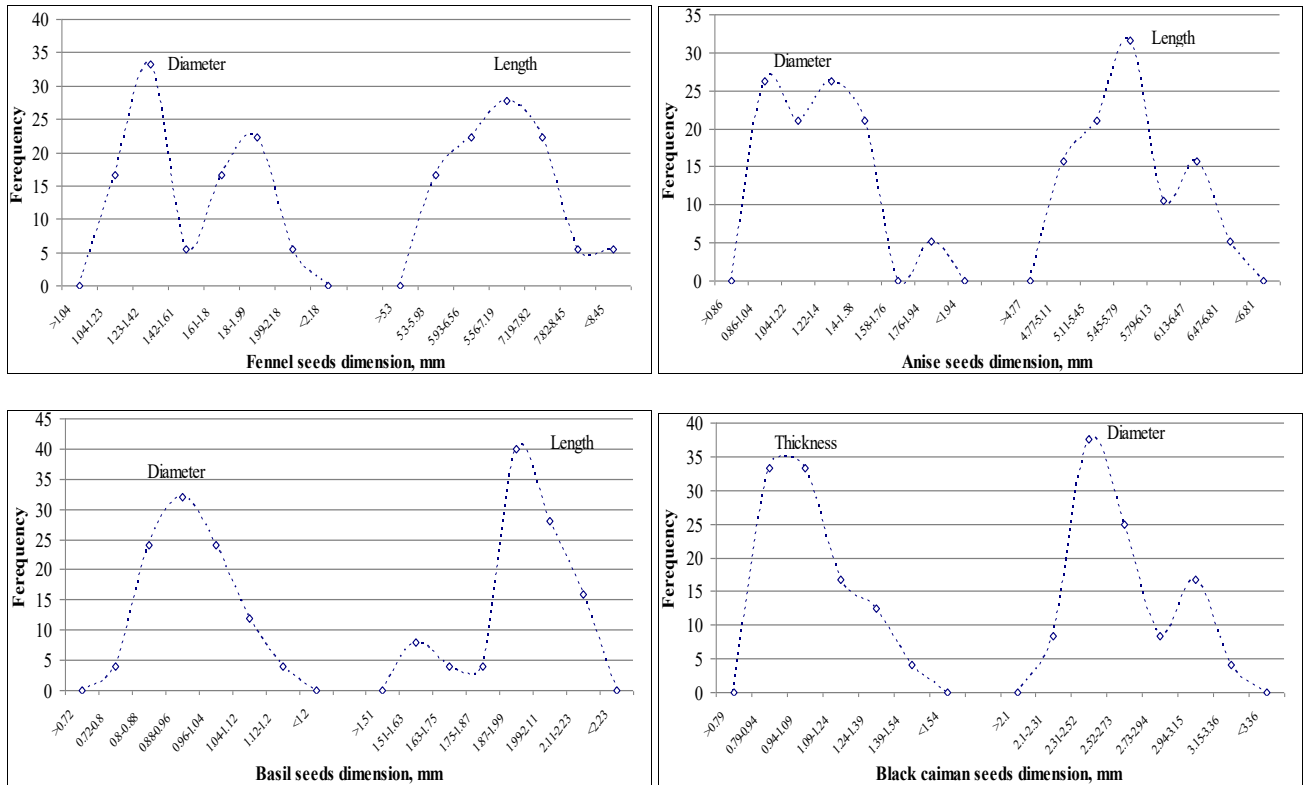


Fig 1: The frequency of the main dimensions for medicinal and aromatic seeds

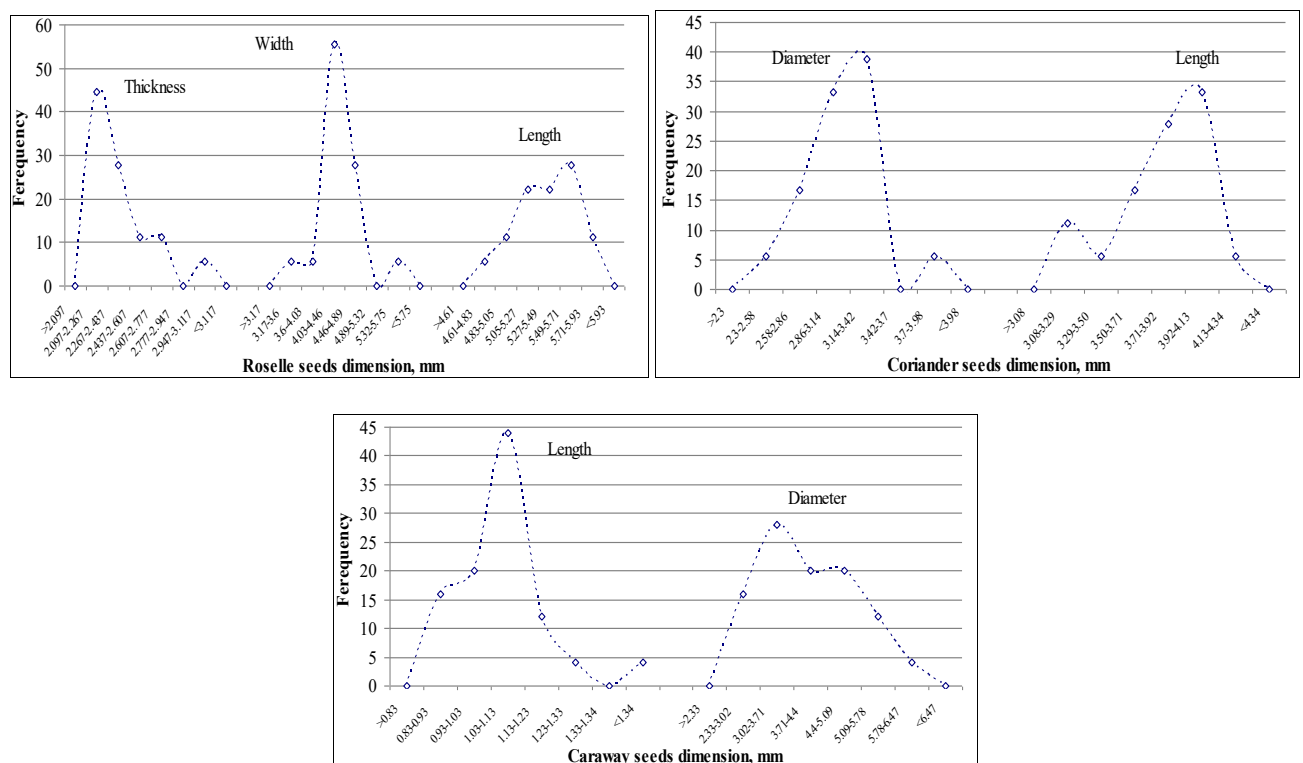


Fig 1: The frequency of the main dimensions for medicinal and aromatic seeds

The average of the biggest dimension of the medicinal and aromatic seeds were illustrated in Fig 2 these recorded 6.23±0.88, 5.62±0.49, 0.94±0.10, 1.10±0.22, 5.34±0.34, 3.77±0.29 and 1.06±0.10 mm for fennel, anise, basil, black caiman, roselle, coriander and caraway respectively. The average of the GD, AD and A_{fs} of the medicinal and aromatic seeds were tabulated in Table (1). The highest

average data and the standard deviation of GD, AD and A_{fs} were recorded 18.67±3.02, 4.03±0.21 and 1121.60±356 respectively at roselle seeds. On the other sides, the lowest average data and the standard deviation of GD, AD and A_{fs} were recorded 0.62±0.10, 0.96±0.08 and 1.17±0.32 respectively at basil seeds.

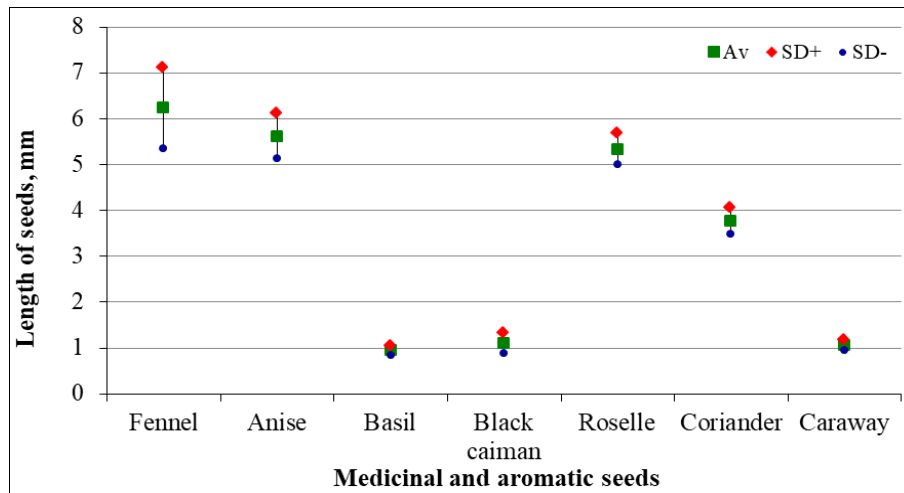


Fig 2: The mean and standard deviations of seeds lengths for the medicinal and aromatic seeds

Table 1: The average and the SD of seeds GD, AD and A_{fs}

Seeds properties Seeds type	GD, mm	AD, mm	A _{fs} , mm ²
Fennel	3.20 ± 0.95	2.59 ± 0.35	34.87 ± 20.02
Anise	2.31 ± 0.56	2.29 ± 0.20	17.72 ± 8.07
Basil	0.62 ± 0.10	0.96 ± 0.08	1.17 ± 0.32
Black caiman	0.96 ± 0.22	1.24 ± 0.12	3.05 ± 1.63
Roselle	18.67 ± 3.02	4.03 ± 0.21	1121.60 ± 356.00
Coriander	3.81 ± 0.57	2.26 ± 0.17	46.60 ± 13.72
Caraway	1.30 ± 0.28	1.60 ± 0.27	5.56 ± 2.32

2. The physical properties of medicinal and aromatic seeds

The physical properties of medicinal and aromatic seeds as volume, roundness, bulk density and mass of 1000 seeds were determined and illustrated in Figs from 3 to 6. From Fig 3 it can see that the average of the volume for the medicinal and aromatic seeds were recorded 12.08±5.76, 6.98±3.03, 2.86±0.66, 5.94±1.93, 56.34±9.27, 27.53±6.77 and 11.98±4.99 mm³ for fennel, anise, basil, black caiman, roselle, coriander and caraway respectively. These results

can used at design the hoppers, containers and pages, raise belts

Furthermore, Fig 4 shows that the average of the roundness for the medicinal and aromatic seeds were recorded 0.36±0.05, 0.33±0.05, 0.73±0.03, 0.69±0.05, 0.72±0.04, 0.79±0.05 and 0.60±0.06 for fennel, anise, basil, black caiman, roselle, coriander and caraway respectively. The roundness important to adjust the select conveyors angle and materials, hoppers sides design, sieve hole shape.

Therefore, Fig 5 demonstrated that the average of the bulk density for the medicinal and aromatic seeds were recorded 68.53±32.52, 115.46±56.01, 224.63±65.13, 119.79±31.41, 12.10±2.15, 25.60±7.77 and 65.64±30.30 g/mm³ for fennel, anise, basil, black caiman, roselle, coriander and caraway respectively. The seeds bulk density useful to determine the size of machine hoppers, containers and pags... etc.

Moreover, Fig 6 confirmed that the average of the mass of 1000 seeds for the medicinal and aromatic seeds were recorded 6.6, 3.3, 1.4, 2.3, 35, 4 and 4.3 g for fennel, anise, basil, black caiman, roselle, coriander and caraway respectively.

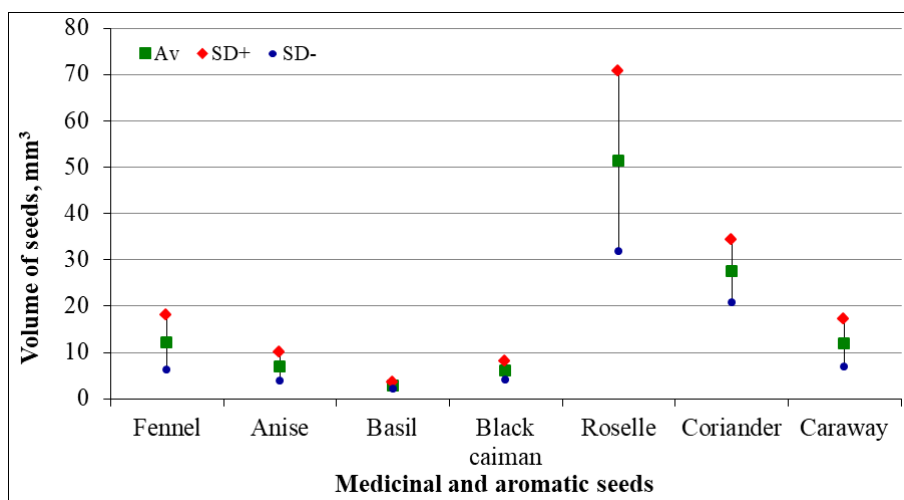


Fig 3: The mean and standard deviations of seeds volume for the medicinal and aromatic seeds

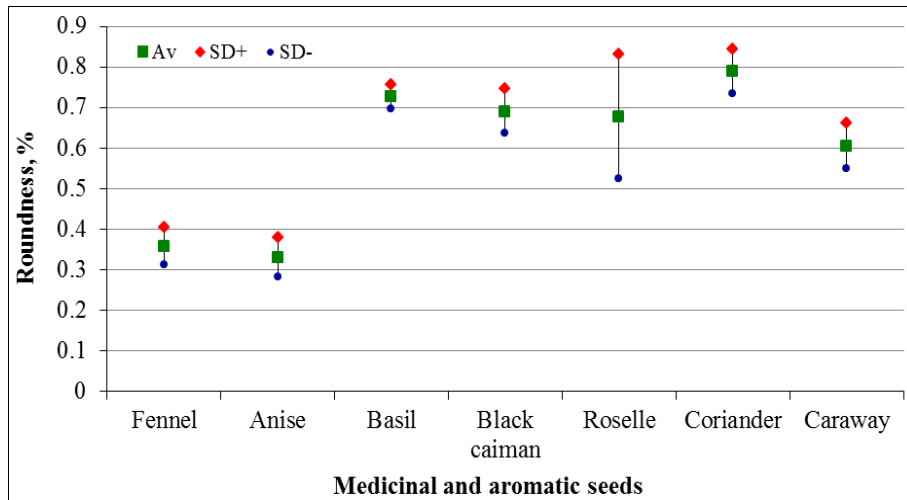


Fig 4: The mean and standard deviations of seeds roundness for the medicinal and aromatic seeds

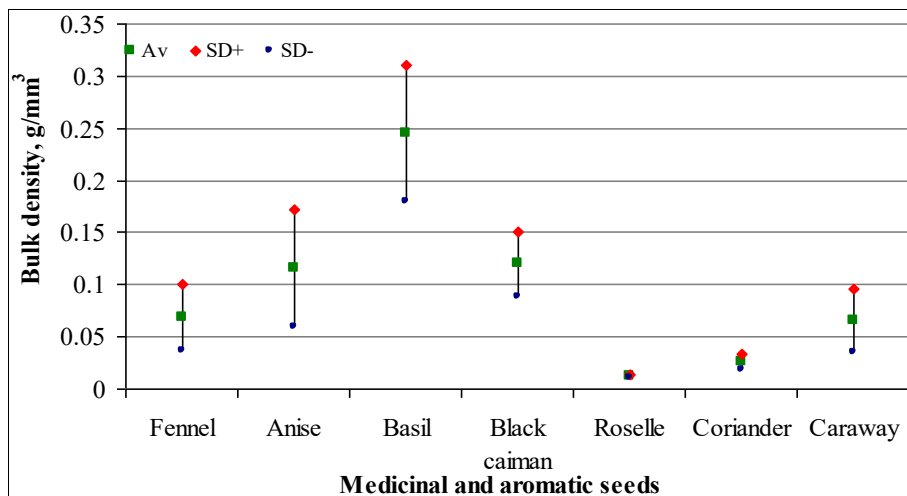


Fig 5: The mean and standard deviations of seeds bulk density for the medicinal and aromatic seeds

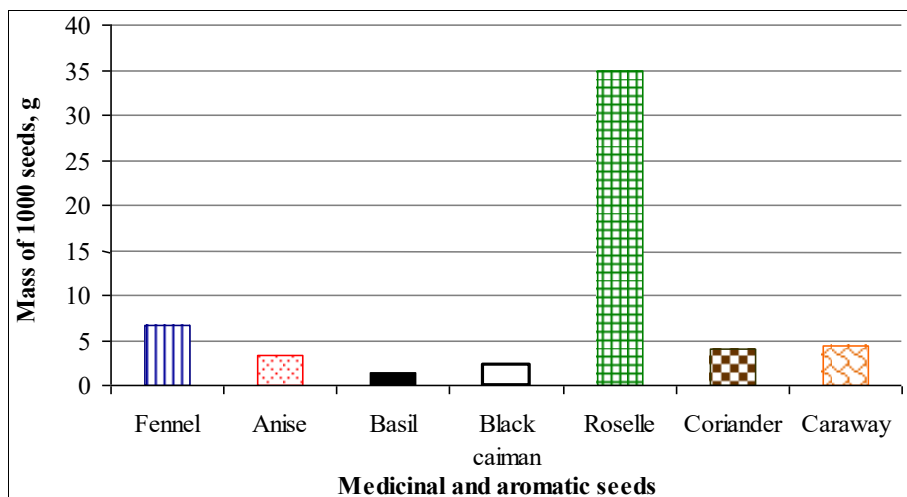


Fig 6: The mean and standard deviations of mass of 1000 seeds for the medicinal and aromatic seeds

The linear multiple regression models of the relationship between the each of volume, bulk density and roundness with the main dimensions of the medicinal and aromatic seeds under study have the highly significant effect. The multiple regression models and the regression coefficient were tabulated in Tables from (2 to 4). Generally, the models clear that the all-seeds bulk density have an inversely relationship with the main seed's dimensions. Then the direct relationships were found with the seeds

volume. However, the roundness models have an inversely relationship with the seed's length at fennel, anise, roselle and coriander seeds types. But it had a direct relationship with the seed's diameters and/or width and thickness at the above seed's types. Also, the seeds types of basil, black caiman and caraway had a direct relationship with seeds length and had an inverse relationship with seeds diameters and/or thickness. From the tables cleared that the highest appropriate regression coefficients of (R2 = 0.9691, 0.9973

and 0.9964) for bulk density, volume and roundness respectively followed by black caiman, coriander, caraway, anise, fennel, and basil for seeds volume. Thus, the gradient of the regression coefficients were basil, fennel, black caiman, anise, coriander and caraway, respectively for seeds bulk density. However, the gradient of the regression coefficients were anise, coriander, basil, fennel, black caiman and caraway, respectively for seeds roundness. On the other sides the high P-Value effect at seeds volume were done at seeds diameter for all medicinal and aromatic seeds and seeds width for roselle seed. These trends found also at seeds bulk density. But the high P-Value effect at roundness of seeds have the same behavior of seeds diameter for the all-seeds types except the basil seeds and black caiman seeds it found at seeds thickness, and at roselle seeds it found at seeds length.

Table 2: The modileng and regrission coefficient of medicinal and aromatic seeds bulk density, in the face of the main dimension's seeds

Type of seeds	Models	R ²
Fennel	B = 259.98 - 9.74 L - 85.91 D	0.9478
Anise	B = 539.96 - 36.51 L - 179.24 D	0.9289
Basil	B = 1059.30 - 245.06 T - 299.14 D	0.9679
Black caiman	B = 432.54 - 93.27 T - 80.47 D	0.9302
Roselle	B = 50.097 - 2.32 L - 3.21 W - 4.83 T	0.9691
Coriander	B = 116.68 - 9.30 L - 18.52 D	0.9144
Caraway	B = 233.83 - 54.077 L - 29.133 D	0.8373

Table 3: The modileng and regrission coefficient of medicinal and aromatic seeds volume, in the face of the main dimension's seeds.

Type of seeds	Models	R ²
Fennel	V = -23.06 + 1.92 L + 15.21 D	0.9880
Anise	V = -11.58 + 0.93 L + 10.85 D	0.9848
Basil	V = -5.32 + 3.24 T + 2.63 D	0.9918
Black caiman	V = -13.26 + 5.61 T + 4.99 D	0.9747
Roselle	V = -108.56 + 10.043 L + 12.227 W + 23.991 T	0.9973
Coriander	V = -50.55 + 6.29 L + 17.97 D	0.9768
Caraway	V = -27.727 + 13.45 L + 6.89 D	0.9777

Table 4: The modileng and regrission coefficient of medicinal and aromatic seeds roundness, in the face of the main dimensions seeds.

Type of seeds	Models	R ²
Fennel	S = 0.367 - 0.040 L + 0.156 D	0.9939
Anise	S = 0.321 - 0.038 L + 0.183 D	0.9964
Basil	S = 0.746 + 0.251 T - 0.134 D	0.9949
Black caiman	S = 0.695 + 0.205 T - 0.089 D	0.9929
Roselle	S = 0.734 - 0.092 L + 0.055 W + 0.094 T	0.9964
Coriander	S = 0.802 - 0.140 L + 0.170 D	0.9955
Caraway	S = 0.609 + 0.178 L - 0.051 D	0.9717

3. Bio-properties of medicinal and aromatic seeds soaking time on the seeds moisture content

The fact of soaking operation and time is effects of the fast germination after cultivate (Cheong and Lim, 2023) [10]. At the results as shown in Fig (7) the increase of soaking time to about one-hour effects on the moisture contents of medicinal and aromatic seeds at 0.0, 30.0, 45.0, and 60.0 min. The data cleared that at dry seeds the highest moisture contents were recorded at roselle seeds followed by caraway then black caiman, anise, coriander, basil, and fennel. These moisture contents increased of about 79.07, 66.76, 79.04, 56.74, 29.41, 68.62 and 55.38 % respectively for fennel, anise, basil, black caiman, roselle, coriander and caraway at increase the soaking time from 0.0 to 60.0 min. Also, it can note that, the seeds of basil prefer un-soaked because, appear the phenomena of coated by the gelatinoids cover directly after soaking in water. Furthermore, some seeds need more soaking time to impact its seed covers as roselle and black caiman. Generally, the change in seed moisture content resulting from the soaking process varies according to the nature of the seeds and the hardness of seed walls, which affects some of the biological, physical and mechanical properties of the seeds (Balakrishnan *et al.*, 2011 and Chatchavanthatri *et al.*, 2020) [1, 8]. Also Mutia and Diyanti (2022) [25] confirmed that the soaking operation of seeds can loosen the covers, opened that pores, that activate the growing enzymes to quick germination.

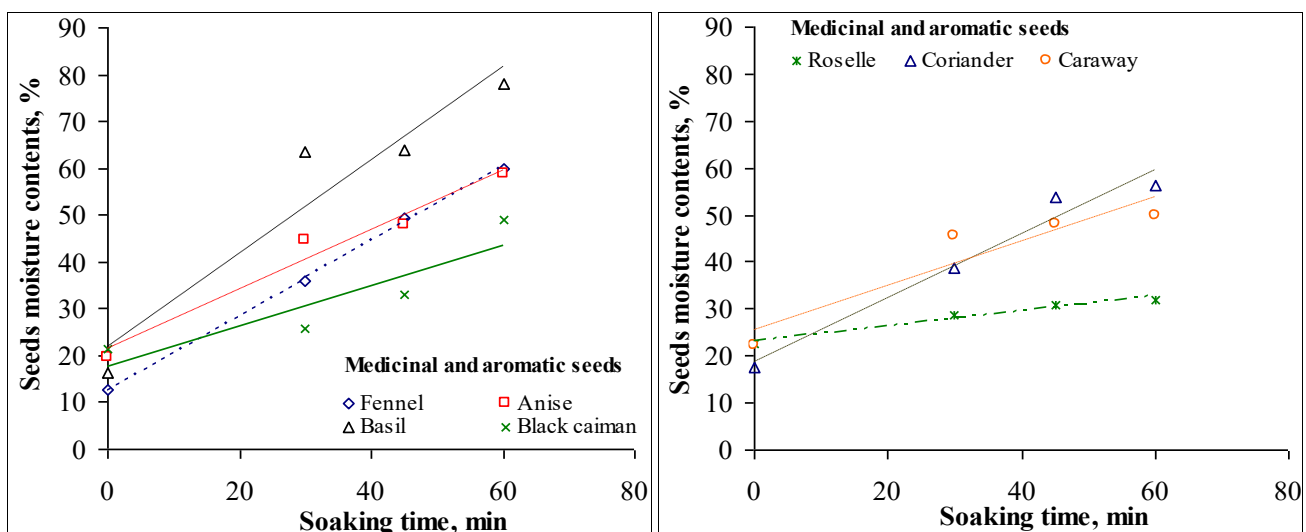


Fig 7: Effect of soaking time medicinal and aromatic seeds on the seed's moisture content

4. The mechanical properties of medicinal and aromatic seeds

The medicinal and aromatic seeds of fennel, anise, basil, black caiman, roselle, coriander and caraway friction

coefficient on the galvanized plate were affect the moisture content as showed in Fig. (8). The figure clear that the coefficient of friction for fennel, black caiman coriander and coriander were increase of about 567.05, 75.06 and 14.58 %

at the moisture content increased from about 20.56 to 60 %, 21.24 to 49.09 and 37.68 to 56.35 % respectively. Thus, the other friction coefficient for anise and caraway were decreased of about 69.15 and 1.17%. While, the friction coefficient for roselle seeds un-change at dry and wet, after

only one hour soaking, that the moisture content increase from 22.46 to 31.82%. But the repose angle of basil can't measure after wet that make a mass grouping by the gelatinized cover.

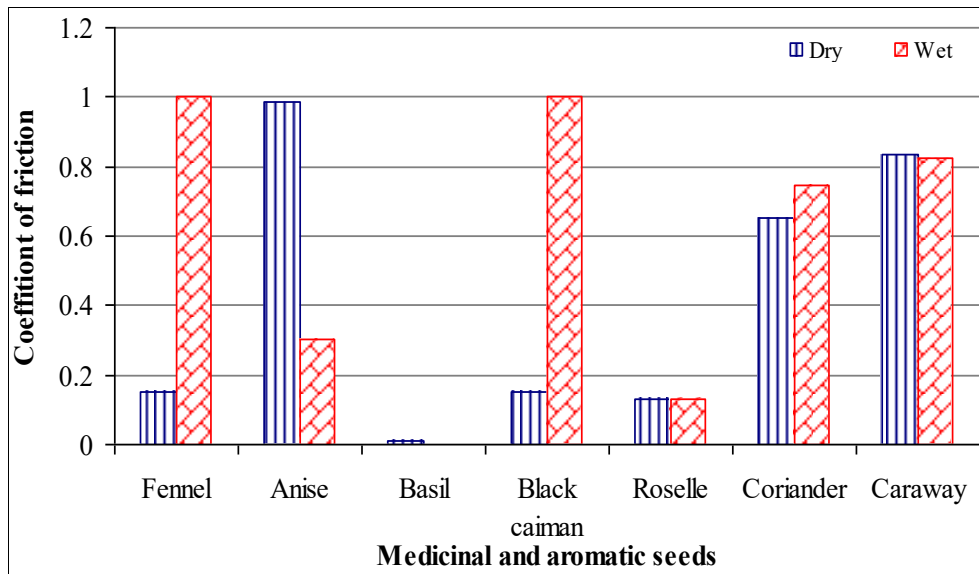


Fig 8: The average of coefficient of friction for the dry and wet medicinal and aromatic seeds

The medicinal and aromatic seeds of fennel, anise, basil, black caiman, roselle, coriander and caraway repose angle were high affect the moisture content as illustrated in Fig. (9). The figure clear that the repose angle for fennel and anise were diminish of about 23.52 and 14.75 % at the moisture content increased from about 20.56 to 60 % and 39.57 to 58.87 % respectively. Thus, the other repose angle

for roselle, coriander and caraway were rise of about 27.36, 13.97 and 5.85%. While, the repose angle for black caiman seeds un-change at dry and wet, after only one hour soaking, that recorded about 32.51°. But the repose angle of basil can't measure after wet that make a mass grouping by the gelatinized cover.

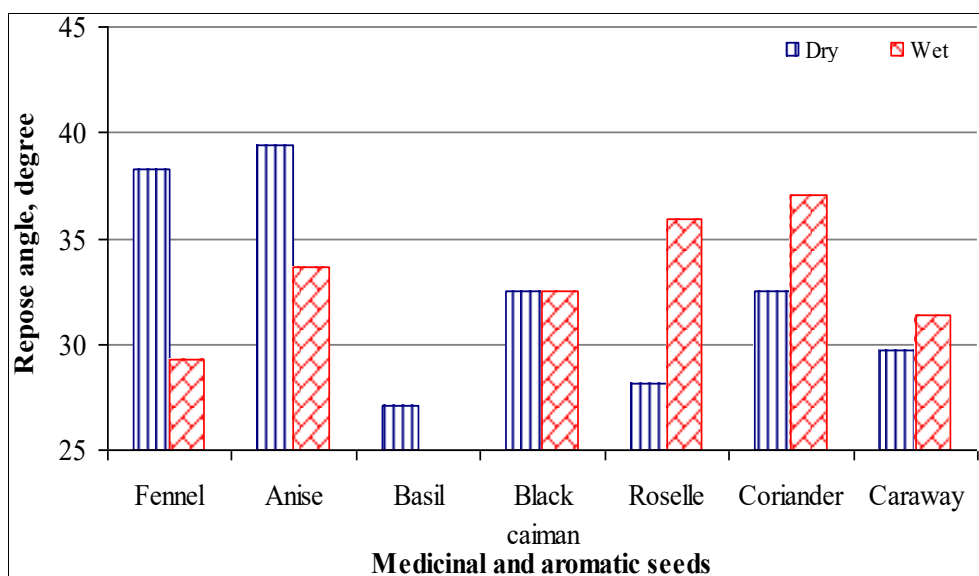


Fig 9: The average of repose angle for the dry and wet medicinal and aromatic seeds

The results of the coefficient of friction and the repose show that some seeds were greatly affected by the soaking process for an hour or less. While the outer shells of others were not affected by the soaking process. But some seeds should not be soaked or planted using the Harrati agriculture method (wet seed in wet soil). Practically the research's signed that the importance of relationship between the friction coefficient and the repose angle at design the agricultural

machinery especially the hoppers and belts tilt angles according the results from Ghazy *et al.* (2021)^[16] and Cheng *et al.* (2022)^[9]

5. The aerodynamic properties of medicinal and aromatic seeds

Moreover, Fig 10 established that the average of the seed's terminal velocity for the medicinal and aromatic seeds were

1.04, 1.02, 4.20, 1.09, 2.20, 1.24 and 1.5 m/s for fennel, anise, basil, black caiman, roselle, coriander and caraway respectively. These mean that the highest terminal velocity was 4.20 m/s found at the heavy seed of roselle. Thus, the lowest terminal velocity was 1.02 m/s found at light seeds of

anise. These information data useful can using and design at the systems of the pneumatic planter (Hu *et al.*, 2022, Ismail *et al.*, 2008 and Ismail *et al.*, 2022)^[17, 18, 19, 20], aero-cleaner and transport and handling systems.

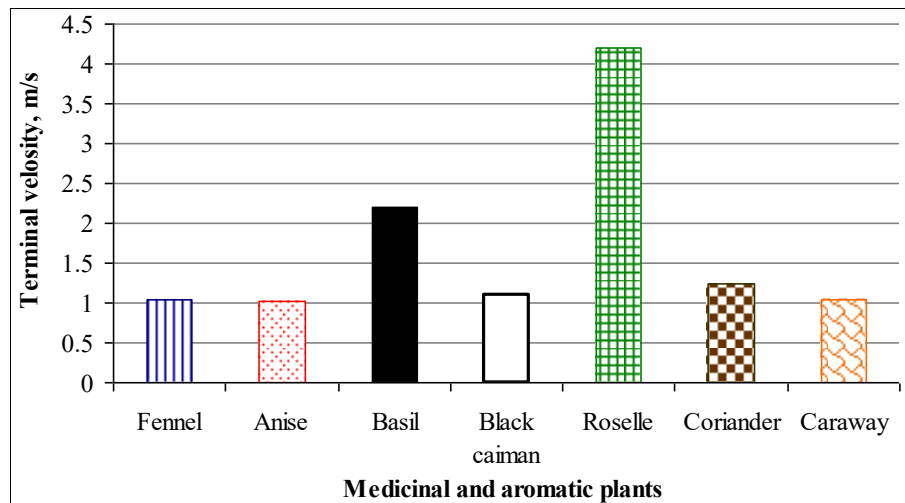


Fig 10: The average of terminal velocity for the medicinal and aromatic seeds

Conclusion

The results concluded that the linear models have a perfect to describe the relation between the each of bulk density, volume and roundness with the main dimensions of different seeds under study. It recorded the highest regression coefficient 0.969, 0.997 and 0.996 respectively for bulk density, volume and roundness at roselle seeds. Thus, the corresponding lowest regression coefficients were 0.837, 0.975 and 0.972 respectively for caraway, black caiman and caraway. Moreover, the soaking process effect by increase the seeds moisture contents ranging by between 79.07 and 29.41 %. Knowing that, the soaking process mainly effect on the seed's coefficients of friction and the repose angles which it highest increase of about 85.01 and 79.07% and the lowest were recorded 12.73 and 29.41%. On the other side, the highest and lowest terminal velocity were 4.2 and 1.02 recorded at roselle and anise seeds. From the results it can recommended that the linear models have a perfect to describe the relation between the each of bulk density, volume and roundness with the main dimensions of different seeds under study. The study recommends the possibility of applying the resulting mathematical models to obtain results that help in designing the appropriate size and capacity of tanks. Appropriate angles and manufacturing materials can also be selected according to the moisture content of the seeds, the coefficient of friction, and the stacking angle in agricultural machinery, transport, handling, and storage equipment

References

- Balakrishnan M, Manikantan MR, Viswanathan R, Sreenarayanan VV. Moisture dependent physical properties of cardamom. Institute of Agrophysics, Polish Academy of Sciences,2011:25:399–402.
- Balkrishna A, Sharma H, Kukreti A, Kumari A, Saini P, Arya V, *et al.* Traditional uses and phytopharmacology of *Cirsium arvense*: Bioprospecting potential of a weed from temperate biome. Journal of Applied Pharmaceutical Science,2024:14(5):030–037.
- Benamar K, Koraichi SI, Benbrahim KF. Ethnobotany, phytochemistry and pharmacological activities of *Celtis australis*: A review. Journal of Herbal Medicine and Pharmacology,2023:12(1):54–72. doi:<https://doi.org/10.34172/jhp.2023.05>
- Benamar K, Koraichi SI, Fikri-Benbrahim K. Ethnobotany, phytochemistry, and biological properties of three naturally associated Mediterranean species. Journal of Applied Pharmaceutical Science,2025:15(02):019–036. <http://www.japsonline.com> DOI:10.7324/JAPS.2025.0205567 ISSN 2231-3354.
- Benamar K, Koraichi SI, Benamar S, Benbrahim KF. Manuscript ethnomedicinal use of plants by Ain Chkef (North Central Morocco) community to boost immunity and overcome SARS COV-2 infection. Ethnobotany Research and Applications,2024:29:1–17. doi:<http://dx.doi.org/10.32859/era.29.6.1-17>
- Benkhaira N, El Hachlafi N, Jeddi M, Abdnim R, Bnouham M, Koraichi SI, *et al.* Unveiling the phytochemical profile, *in vitro* bioactivities evaluation, *in silico* molecular docking and ADMET study of essential oil from *Clinopodium nepeta* grown in Middle Atlas of Morocco. Biocatalysis and Agricultural Biotechnology,2023:54:102923–1038. doi:<https://doi.org/10.1016/j.bcab.2023.102923>
- Bhatt P, Pant S, Bhardwaj S, Sneha S, Dobhal P, Baunthiyal M, *et al.* Critical review on nutritional, bioactive and medicinal potential of *Bunium persicum*. Exploration of Drug Science,2025:3:100893. <https://doi.org/10.37349/eds.2025.100893>
- Chatchavanthatri N, Junyusen T, Moolkaew P, Arjharn W, Junyusen P. Effect of soaking and sprouting treatment on germination rate of paddy. E3S Web of Conferences,2020:187:04016. <https://doi.org/10.1051/e3sconf/202018704016>
- Cheng Y, Treado JD, Lonial BF, Habdas P, Weeks ER, Shattuck MD, *et al.* Hopper flows of deformable particles. Soft Matter,2022:18:8071–8086.

10. Cheong PW, Lim MW. Influence of moisture content on seed germination and plant growth efficiency. AIP Conference Proceedings,2023:2847:030007. <https://doi.org/10.1063/5.0165329>
11. Chraibi M, Farah A, Balouiri M, Barkai H, Sadiki M, Benbrahim KF, *et al.* Chemical characterization and antimicrobial activity of Moroccan Pelargonium asperum essential oil. Journal of Applied Pharmaceutical Science,2016:6(12):042–046. doi:<https://doi.org/10.7324/JAPS.2016.601206>
12. Du X, Liu C, Liu C, Sun Q, Chen S. A novel method for measurement of the angle of repose of granular seeds in discrete element methods. Journal of Agricultural Engineering,2023:54:1504.
13. Fawal YA, Ismail NK, Mousa EH. Some physical and engineering properties of sugar beet seeds in relation with some agricultural mechanical. Journal of Agricultural Science Mansoura University,2008:33(1):273–282.
14. Gao X, Cui T, Zhou Z, Yu Y, Xu Y, Zhang D, *et al.* DEM study of particle motion in novel high-speed seed metering device. Advanced Powder Technology,2021:32:1438–1449.
15. García JLG, Rodríguez AVC, Valdés MHR, Godina FR, Olivo AR, Osuna HTG, *et al.* Micro and nanoencapsulation of bioactive compounds for agri-food applications: A review. Industrial Crops and Products,2022:186:115198–115211. <https://doi.org/10.1016/j.indcrop.2022.115198>
16. Ghazy MI, Ismail NK, Al-Ghobashy ZS, Ismail ZI. Influence of inverse pulsation on the crushed maize flow rate from hoppers. Misr Journal of Agricultural Engineering,2021:39(3):375–390. doi:<https://doi.org/10.21608/mjae.2022.136171.1073>
17. Hu M, Xia J, Zhou Y, Luo C, Zhou M, Liu Z, *et al.* Measurement and calibration of the discrete element parameters of coated delimited cotton seeds. Agriculture,2022:12:286. <https://doi.org/10.3390/agriculture12020286>
18. Ismail ZE, Ismail NK, Elsis AA. Fennel seeds planting by investigated novel pneumatic technology. Journal of Soil Sciences and Agricultural Engineering Mansoura University,2022:13(2):43–50.
19. Ismail ZE. Developing the metering unit of the pneumatic planter 1: The factors affecting seed-metering unite performance. Journal of Agricultural Science Mansoura University,2008:33(9):6511–6525.
20. Ismail ZE. Developing the metering unit of the pneumatic planter 2: The injection planting seed. Journal of Agricultural Science Mansoura University,2008:33(10):7317–7330.
21. Ismail ZE, El-Hanify EH, Ismail NK. The utilization of a metering plate device for cowpea planting. Journal of Agricultural Science Mansoura University,2009:34(5):5853–5867.
22. Kimmelshue CL, Goggi S, Moore KJ. Seed size, planting depth, and a perennial groundcover system effect on corn emergence and grain yield. Agronomy,2022:12:437. <https://doi.org/10.3390/agronomy12020437>
23. Li Z, Wu J, Du J, Duan D, Zhang T, Chen Y, *et al.* Experimenting and optimizing design parameters for a pneumatic hill-drop rapeseed metering device. Agronomy,2023:13:141. <https://doi.org/10.3390/agronomy13010141>
24. Mohsenin NN. Physical properties of plant and animal materials. Gordon and Breach Science Publishers, 1986, New York.
25. Mutia YD, Diyanti AR. Pengaruh perendaman air dingin terhadap perkecambahan benih cemara laut (Casuarina equisetifolia L.). Jurnal Embrio,2022:14(1):52–58. <https://doi.org/10.31317/embrio.v14i1.708>
26. Nakra S, Tripathy S, Srivastav PP. Drying as a preservation strategy for medicinal plants: Physicochemical and functional outcomes for food and human health. Phytomedicine Plus,2025:5:100762. www.sciencedirect.com/journal/phytomedicine-plus
27. Pal R, Kumar R, Tripathi A, Chaudhary S, Satyartham, Singh V, *et al.* Perspective analysis of the physical and engineering properties of coriander seed at different moisture contents. International Journal of Plant and Soil Science,2023:35(21):11–22.
28. Putri KD. The effect of planting media and seed soaking on the growth of true shallot (Allium ascalonicum L.) seeds. Journal of Agrosociology and Sustainability,2024:1(2):100–110. <https://doi.org/10.61511/jassu.v1i2.2024.308>
29. Rajani Bhat, Shetty GR, Rajasekharan PE, Pooja DA, Ganapathi M, Nadukeri S, *et al.* Effect of pre-sowing seed treatments on Aristolochia tagala Cham. International Journal of Current Microbiology and Applied Sciences,2020:9(10):1803–1808. <https://doi.org/10.20546/ijemas.2020.910.219>
30. Rastogi V, Porwal M, Sikarwar MS, Singh B, Choudhary P, Mohanta BC, *et al.* A review on phytochemical and pharmacological potential of Bhut Jolokia (Capsicum chinense Jacq.). Journal of Applied Pharmaceutical Science,2024:14(5):079–090. <https://doi.org/10.7324/JAPS.2024.175359>
31. Razavi SMA, Yeganehzad S, Sadeghi A. Moisture dependent physical properties of canola seeds. Journal of Agricultural Science and Technology,2009:11:309–322.
32. Srivastava AE. Engineering principles of agricultural machines. American Society of Agricultural Engineers, 1995.
33. Sun K, Yu J, Liang L, Wang Y, Yan D, Zhou L, *et al.* A DEM based general modelling method and experimental verification for wheat seeds. Powder Technology,2022:401:117353.
34. Tawfik HAH. Developing an automatic mechanism for precision seeder. MSc Thesis, Faculty of Agriculture, Mansoura University, 2014.
35. Wang Y, Zhang D, Yang L, Cui T, Jing H, Zhong X, *et al.* Modeling the interaction of soil and a vibrating subsoiler using the discrete element method. Computers and Electronics in Agriculture,2020:174:105518.
36. Yurtlu YB, Yesiloglu E, Arslanoglu F. Physical properties of bay laurel seeds. Institute of Agrophysics, Polish Academy of Sciences,2010:24:325–328.
37. Zamani S, Fathi M, Ebadi MT, Máthé À. Global trade of medicinal and aromatic plants: A review. Journal of Agriculture and Food Research,2025:21:101910.