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Physical characteristics of colza seeds treated and coated with different filling materials

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The knowledge about the physical characteristics of seeds, whether coated or not, is essential for the design of machines and equipment. Therefore, the objective of this work was to determine the physical characteristics of colza (*Brassica napus* L.) seeds coated with bentonite, gypsum and kaolin, treated with fungicide (carboxin + thiram) and aqueous extract of black pepper (*Piper nigrum* L.). The untreated colza seeds were submitted to the coating process using bentonite, gypsum and kaolin as fillers, and as treatment products were used as fungicide (carboxin + thiram) and an aqueous extract of black pepper which were added to an aqueous solution of 30% PVA glue (cementing mixture). Then the physical characteristics were determined: diameter, number of times increased, porosity, angle of repose, resistance, classification in sieves and weight of one thousand seeds. The experiment was organized in a completely randomized design and arranged in a factorial scheme. The means, when necessary, were compared by the Scott-Knott test. The colza seeds coated with bentonite presented greater diameter, number of times increased, porosity, angle of repose and weight of a thousand seeds, followed by gypsum and kaolin. The treatment products had little influence on the physical characteristics of the coated seeds.

Key words: *Brassica napus* L., diameter, resistance, weight of one thousand seeds.

INTRODUCTION

The colza seed (*Brassica napus* L.), or its improved variety, the canola, (*B. napus* L. ssp. *oleifera*) is one of the main oilseeds in the world. It has been used as green fodder for animal feed, fertilizer for soil conditioning and raw material for oil extraction, which has been used in human food, lighting, industrial use and more recently for the production of biofuel (Mori et al., 2014). However, its seeds are small in size, making it difficult to use them in

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the mechanized planting, and if they are sown broadcast, there is a risk of wind drift.

According to Duran and Retamal (1989), small and irregular seeds hinder precision sowing, when under certain circumstances the producer uses higher amounts of seeds in the establishment of the production fields to obtain the desired final stand.

In order to solve this problem, specialists have suggested the study of techniques for seed coating, where inlaying/pelletizing is indicated because of the use of a dry, inert material of fine granulometry and a cementing material (adhesive). This treatment allows the seed to obtain a rounded form, increasing its size and facilitating its distribution, be it manual or mechanical (Mendonça et al., 2007).

Although the technique has been developed for several years, information about the composition of the materials used and the coverings preparation are little spread, since this technique remains inaccessible along the seed companies and the companies that process coated/ pelleted seeds (Silva et al., 2002). The materials used in the coating/pelletizing process, including those of covering, adhesives and finishing, have influence in the final rigidity of the seed, in the water absorption and in the gas exchange between the seed and the external environment to the seeds; and all these aspects affect directly the germination (Silva, 1997; Silva and Nakagawa, 1998).

Additionally, there is the possibility of nutrients incorporation, growth regulators and other agrochemicals (insecticides and fungicides) during the coating/pelletizing process, which may constitute improvements in the seed health and in the seedling establishment (Silva et al., 2002). The use of plants with bioactive potential, in the form of extracts, oils and powders, against various organisms has been increasingly encouraged. Several researchers such as Cardoso et al. (2005), Bomtempo (2007), Bong (2010), Abbasi et al. (2010) and Khan et al. (2010) state that the piperine, main compound found in the black pepper (*Piper nigrum* L.), has a recognized cytotoxic, anti-inflammatory, antipyretic, analgesic, antioxidant, antitumor, antifungal and bactericidal activity.

What was been exposed shows the importance of studying filling and cementing materials that are easy to obtain, as well as products that can be used as seed treatment. Thus, the objective of this work was to determine the diameter, number of times increased, porosity, angle of repose, weight of one thousand seeds and resistance of colza (*Brassica napus* L.) seeds coated with bentonite, gypsum and kaolin and treated with fungicide or aqueous extract of black pepper (*P. nigrum* L.).

MATERIALS AND METHODS

Location of the experiment

The experiment was realized at the Laboratory of Storage and Processing of Agricultural Products (LAPPA), in the Federal University of Campina Grande, Campus of Campina Grande, Paraíba, Brazil.

Acquisition of the seeds

The seeds were purchased at the local trade of the city of Campina Grande, Paraíba, Brazil. After acquisition, the seeds were taken to the Laboratory for cleaning and removal of impurities that accompanied the seeds.

Preparation of the plant extract

The black pepper fruits (*P. nigrum* L.) were acquired at the central fair of the city of Campina Grande, Paraíba, Brazil. The aqueous extract was obtained from the fruits powder, which were weighed, dampened with distilled water, and left for maceration for 72 h, at room temperature of 24.0 ± 4.0°C in the absence of light and shaken daily for five minutes. The amount of powder used corresponded to 20% of the water volume. Subsequently, the solutions were filtered on filter paper, and the extract stored in an amber glass container with a capacity of 0.5 L (Almeida et al., 2004).

Materials and seed coating process

Three filling materials were used: (1) bentonite, (2) gypsum and (3) kaolin. As cementing material the PVA glue was used at the percentage of 30% for each filling material. As treatment products it was used as the aqueous extract of black pepper (*Piper nigrum* L.) and the carboxin + thiram fungicide corresponding to 50% of the mixture of each product, using 20% of distilled water to compose 100% of the mixture. The seed coating process occurred by the alternated application of cementing material and filling material. This process was repeated until all material destined to the process has been fully utilized.

Physical characteristics of the coated and treated seeds

Seed diameter and number of times increased

To determine the diameter of the coated seeds it was used as digital pachymeter with precision of 0.01 mm, using four repetitions of 25 seeds for each treatment. The results were expressed in millimeters (mm). The number of times increased was calculated by the ratio of the diameter of the coated seed to the bare seed. For statistical analysis, the mean of each 25 seeds was considered as repetition.

Classification by size

For the classification of the coated seeds by size, four subsamples of about 50 g were used per treatment. Each subsample was subjected to analysis by overlapping screen sieves of 1.0, 1.5, 2.5 and 4.0 mm. The set of sieves was shaken for a minute. The sieved fractions, including the portion that passed through the smaller sieve, were weighed and the weights of the fractions were expressed as a percentage of the total weight.

Porosity

The porosity was determined by the direct method, in which it was

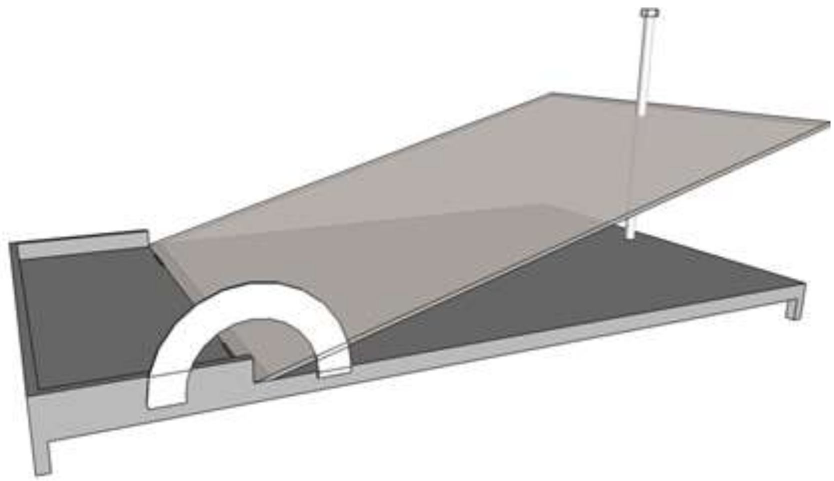

Figure 1. Equipment used to determine the angle of repose of colza (*Brassica napus* L.) seeds coated with bentonite, gypsum or kaolin and treated with fungicide or aqueous extract of black pepper (*Piper nigrum* L.).

obtained by adding a known volume of liquid sufficient to complement the empty spaces of the seed mass, using a burette and a measuring cylinder of 50 mL, in which one of them contained soybean oil and the other contained colza seeds coated with one of the combinations. As the oil was added to the measuring cylinder with seeds, it filled the empty spaces. By the difference between the amount of oil added to the measuring cylinder and the one contained in the burette with oil, the porosity of the coated seed mass was determined.

Angle of repose

In order to determine the angle of repose of the coated seeds it was used as an equipment made from a board with dimensions of 22 cm × 38 cm and an acrylic sheet with dimensions of 21 cm × 30 cm. These two pieces are joined by two hinges on one side. On the opposite side there is a screw that when it is screwed, lifts up the acrylic piece. On the same side of the hinges there is a protractor, located at the vertex formed between the board and the acrylic sheet. The moment when the seeds (2.0 g), which are located on the upper face of the acrylic sheet, move fully down, the angle in the protractor is measured (Figure 1).

Weight of one thousand seeds

To determine the weight of one thousand seeds, each combination of filling material and treatment product in thousand seeds were counted by replicate. After this, the seeds were weighed in a digital scale of precision and the data expressed in grams.

Resistance

To determine the percentage of resistant seeds, four repetitions of 100 colza seeds coated with bentonite, gypsum and kaolin, and treated with fungicide and aqueous extract of black pepper were used. These seeds were thrown at a 1.5 m height over a metal surface. This height was adopted because it is the average height in which the seeds are discharged in the seed tanks of the mechanized seeders. After that, the intact seeds out of the damaged ones were counted and the values transformed in percentage of the seeds that resisted the fall.

Experimental design and statistical analysis

The experiment was arranged in a completely randomized design. For the variables resistance and quantity of times increased, the factorial scheme 3 x 2 was used, as it did not require comparison with the control (bare seed) and for the other variables the factorial scheme 4 x 2 (filling materials x treatment products) was used. Each treatment was repeated four times. The data were submitted to Analysis of Variance ($P \leq 0.05$) and the means, when necessary, were compared by the Scott-Knott test ($P \leq 0.05$). For the values of the classification by size in the sieves, the means for each combination of filling material and treatment were presented, adding the standard error.

RESULTS

In Table 1, the mean squares values for seed diameter (SD), number of times increased (NTI), porosity (P), angle of repose (AR), weight of one thousand seeds (WTS) and resistance (R) of colza seeds coated with bentonite, gypsum and kaolin, and treated with fungicide (carboxin + thiram) and aqueous black pepper extract are organized. It was verified that there was an interaction effect between the factors for all the variables studied, except seed diameter (SD) and number of times increased (NTI). For the other variables there was an interaction effect between factors at 1 or 5% probability.

It is observed in Table 2 that there was no statistical difference between the treatment products within each filling material. There was also no statistical difference between the filling materials within each treatment product. On the other hand, for the means of the factor "filling materials" a statistical difference was observed

Table 1. Mean squares referring to seed diameter (SD), porosity (P), angle of repose (AR), weight of thousand seeds (WTS), number of times increased (NTI) and resistance (R) of colza seeds (*Brassica napus* L.) coated with different filling materials (FM) and treated with two treatment products (TP).

SV	DF	Mean Square				DF	Mean Square	
		SD	P	AR	WTS		NTI	R
FM	3	4.54**	522.03**	205.78**	424.98**	2	0.53**	12558.87**
TP	1	0.04ns	0.78ns	1.53ns	1.50*	1	0.02ns	222.04**
FM x TP	3	0.01ns	6.11**	1.95*	1.56**	2	0.01ns	260.04**
Error	24	0.01	0.718	0.41	0.84	27	0.004	4.43

(**) (*) (ns) Significant at 1, 5% and not significant, respectively.

Table 2. Means of the diameter (mm) of the colza seeds (*Brassica napus* L.) coated with bentonite, gypsum and kaolin, and treated with fungicide (carboxin+thiram) and aqueous extract of black pepper (*Piper nigrum* L.).

Filling materials	Treatment products		Means
	Fungicide	Plant extract	
Control	1.81 ± 0.005	1.81 ± 0.005	1.81 d
Bentonite	3.58 ± 0.056	3.55 ± 0.055	3.57 a
Gypsum	3.16 ± 0.029	3.10 ± 0.065	3.13 b
Kaolin	2.74 ± 0.004	2.54 ± 0.061	2.64 c
Means	2.83 a	2.75 a	2.81

*Means followed by the same lowercase letter in the column and row do not differ by the Scott-Knott test ($P \leq 0.05$). CV% = 3.59.

Table 3. Means of the number of times increased of the colza (*Brassica napus* L.) seeds coated with bentonite, gypsum and kaolin, and treated with fungicide (carboxin+thiram) and aqueous extract of black pepper (*Piper nigrum* L.).

Filling materials	Treatment products		Means
	Fungicide	Plant extract	
Bentonite	1.98 ± 0.027	1.96 ± 0.031	1.97 a
Gypsum	1.75 ± 0.016	1.71 ± 0.036	1.73 b
Kaolin	1.51 ± 0.005	1.41 ± 0.034	1.46 c
Means	1.75 a	1.70 a	1.73

*Means followed by the same lowercase letter in the column and row do not differ by the Scott-Knott test ($P \leq 0.05$). CV% = 3.63.

between the treatments, with lower seed diameter recorded in the control (1.81 mm) and larger diameter when the seeds were coated with bentonite (3.57 mm). The other filling materials generated seeds with intermediate diameters, which were statistically different from each other (Table 2).

When comparing the treatment products within each filling material, as well as the filling materials within each treatment product, no statistical difference was observed (Table 3). However, for the means of the factor "filling materials", a statistical difference was observed, with the highest seed increase when using bentonite (1.97 times) and the lower when using kaolin (1.46 times). When gypsum was used, there was an increase of 1.73 times in relation to bare seed, which is an intermediate value, and statistically different from the other two filling materials.

It can be seen at Table 4 that the use of the treatment products had little influence on the seed classification. When the seeds were coated with bentonite and treated with fungicide or aqueous extract of black pepper, approximately 80% of the seeds were retained in the 1.5 and 2.5 mm sieves. Regarding the use of gypsum, approximately 65% of the seeds coated with this material were retained in the 1.5 mm screen sieve. The other

Table 4. Colza (*Brassica napus* L.) seeds coated with bentonite, gypsum and kaolin, and treated with fungicide (carboxin+thiram) or aqueous extract of black pepper (*Piper nigrum* L.), retained (%) in screen sieves of 1.0; 1.5; 2.5 and 4.0 mm.

Combinations	Classification (mm)			
	1.0	1.5	2.5	4.0
Control	100.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00
Bentonite + fungicide	15.6 ± 0.09	48.1 ± 0.01	34.0 ± 0.10	2.3 ± 0.17
Bentonite + plant extract	13.0 ± 0.28	55.5 ± 0.26	29.9 ± 0.08	1.6 ± 0.06
Gypsum + fungicide	11.4 ± 0.02	69.3 ± 0.22	14.0 ± 0.09	5.2 ±0.29
Gypsum + plant extract	11.7 ± 0.09	61.9 ± 0.10	14.3 ± 0.13	12.0 ± 0.12
Kaolin + fungicide	25.5 ± 0.19	69.0 ± 0.64	1.6 ± 0.30	3.9 ± 0.53
Kaolin + plant extract	29.3 ± 0.04	59.5 ± 0.04	7.1 ± 0.47	4.1 ± 0.41

Table 5. Means of the porosity (%) of the colza (*Brassica napus* L.) seeds coated with bentonite, gypsum and kaolin and treated with fungicide and aqueous extract of black pepper (*Piper nigrum* L.).

Filling materials	Treatment products	
	Fungicide	Plant extract
Control	36.00 ± 0.35^{dA}	36.00 ± 0.35^{dA}
Bentonite	52.75 ± 0.41^{aB}	55.25 ± 0.22^{aA}
Gypsum	51.50 ± 0.25^{bA}	52.00 ± 0.35^{bA}
Kaolin	46.00 ± 0.35^{cA}	44.25 ± 0.54^{cB}

*Means followed by the same lowercase letter in the column and uppercase in the row do not differ by the Scott-Knott test ($P \leq 0.05$). CV% = 1.81.

sieves were responsible for retaining about 35% of the seeds. Similar to the gypsum, when the kaolin was used, most of the seeds were retained in the 1.5 mm sieve (approximately 60%). The sieve of 1.0 mm was responsible for retaining on average 30% of the seeds, and the 2.5 and 4.0 mm sieves retained approximately 10% of the seeds.

When comparing the treatment products within each filling material, it was observed for the control that the mean porosity was of 36%, and for the gypsum the porosity varied from 51.50 to 52.00%. For the bentonite, it was observed that the highest porosity was verified when using the aqueous extract of black pepper (55.25%) and the lowest when using the fungicide (52.75%), differing statistically from each other. Comparing the treatment products within the kaolin, it was verified that the highest porosity occurred when the fungicide was used (46%), differing statistically from the use of aqueous extract of black pepper (44.25%) (Table 5).

Comparing the filling materials within each treatment product it can be verified that for the two treatment products there was a statistical difference between the filling materials, with higher porosity values when using the bentonite (52.75-55.25%). On the other hand, the lowest values of porosity were verified in the control (36%). In relation to the seeds coated with gypsum, it was verified that they exhibited the second highest porosity among the materials, varying from 51.50 to 52.00%. Seeds coated with the kaolin had porosities varying from 44.25 to 46.00%, presenting intermediate values to the control and the gypsum (Table 5).

Comparing the treatment products within each filling material, it has been found that the control had a mean angle of repose of 16°. In relation to the bentonite there was no statistical difference, with angles of repose varying from 25.75 to 26.00°. In relation to the gypsum and the kaolin, the highest angles of repose were observed when using the aqueous extract of black pepper (22.75 and 16.25°, respectively), differing statistically from the angles of repose when using the fungicide (21.50 and 15.00º, respectively).

When comparing the filling materials within each treatment product, it is verified that the control had an angle of repose of 16°. For the fungicide, it was observed that the lowest angle of repose was observed when the kaolin was used (15.00°) and the highest when the bentonite (26.50°) was used. The other filling materials presented intermediate values for the angle of repose, varying from 16.00 to 21.50°. In relation to the aqueous extract of black pepper, it was verified that the lowest angle of repose was obtained when the kaolin was used (16.00°), being statistically equal to the control (16.00°).

Table 6. Means of the angle of repose (º) of the colza (*Brassica napus* L.) seeds coated with bentonite, gypsum and kaolin and treated with fungicide and aqueous extract of black pepper (*Piper nigrum* L.).

Filling materials	Treatment products	
	Fungicide	Plant extract
Control	16.00 ± 0.35 cA	16.00 ± 0.35 cA
Bentonite	26.50 ± 0.25 aA	25.75 ± 0.22 aA
Gypsum	21.50 ± 0.25 bB	22.75 ± 0.22 bA
Kaolin	15.00 ± 0.35 dB	16.25 ± 0.22 cA

*Means followed by the same lowercase letter in the column and uppercase in the row do not differ by the Scott-Knott test ($P \leq 0.05$). CV% = 3.27.

Table 7. Means of the weight of one thousand seeds (g) of colza (*Brassica napus* L.) coated with bentonite, gypsum or kaolin and treated with fungicide or aqueous extract of black pepper (*Piper nigrum* L.).

Filling materials	Treatment products		Means
	Fungicide	Plant extract	
Control	3.603 ± 0.053	3.603 ± 0.053	3.603 ± 0.038 d
Bentonite	20.267 ± 0.545	20.693 ± 0.497	20.480 ± 0.377 a
Gypsum	15.211 ± 0.575	13.591 ± 0.374	14.401 ± 0.447 b
Kaolin	8.895 ± 0.400	8.357 ± 0.296	8.625 ± 0.266 c
Means	11.9938 ± 1.591 a	11.5605 ± 1.596 a	11.7771

*Means followed by the same lowercase letter in the column and uppercase in the row do not differ by the Scott-Knott test ($P \leq 0.05$). CV% = 7.81.

Table 8. Percentage of colza seeds (*Brassica napus* L.) coated with bentonite, gypsum or kaolin and treated with fungicide or aqueous extract of black pepper (*Piper nigrum* L.) resistant to mechanical damage.

Filling materials	Treatment products	
	Fungicide	Plant extract
Bentonite	99.00 ± 0.50 aA	99.50 ± 0.43 aA
Gypsum	40.50 ± 1.64 bA	21.25 ± 1.29 bB
Kaolin	99.50 ± 0.43 aA	100.00 ± 0.00 aA

*Means followed by the same lowercase letter in the column and uppercase in the row do not differ by the Scott-Knott test ($P \leq 0.05$). CV% = 2.75.

On the other hand, the highest angle of repose was observed when using the bentonite (25.75º) (Table 6).

In Table 7 show the mean values for the weight of one thousand colza seeds coated with bentonite, gypsum and kaolin and treated with fungicide and aqueous extract of black pepper. When comparing the treatment products within each filling material, as well as the filling materials within each treatment product, it was verified that there was no statistical difference, with the values of the weight of one thousand seeds varying from 3.603 (control) to 20.693 (bentonite). However, by observing the means of the filling materials factor, a statistical difference can be verified, with the lower weight of one thousand seeds being verified in the control (3.603 g) and the highest one when using the bentonite (20.480 g). The other filling materials presented intermediate weights ranging from 8.625 g (kaolin) to 14.401 g (gypsum).

When comparing the treatment products within each filling material, it is found for the bentonite and the kaolin that there was no statistical difference between the treatment products, with resistances varying from 99.0 to 100.0%. However, when the gypsum was used for coating the seeds, it was verified a higher resistance to the fungicide (40.50%), differing statistically from the use of the plant extract (21.25%) (Table 8).

By comparing the filling materials within each treatment product in relation to the resistance, it was verified that for the two treatment products there was no statistical difference between the bentonite and the kaolin, with values varying from 99.0 to 99.50% for the bentonite and 99.50 to 100.0% for the kaolin. These two filling materials differed statistically from the gypsum, in which the resistance values were of 40.5 and 21.25% for the fungicide and the aqueous extract of black pepper, respectively (Table 8).

DISCUSSION

It was noticed that the filling materials provided changes in the physical characteristics of the colza seeds, especially the bentonite, which stood out over the other materials, presenting higher values for the seed diameter, increasing on average 200% of the original diameter of the seeds. The gypsum was also shown as a material capable of increasing the seed diameter; however, it increased the diameter by an average of 175%. In general, the bentonite generated seeds with larger diameter, followed by gypsum and kaolin.

In relation to the weight of one thousand seeds, all the materials made possible the increase in the weight of the seeds, however, the bentonite and the gypsum stood out for increasing approximately 550 and 400%, respectively, the weight of the seeds. The kaolin provided an average increase of 220%. This is something important because according to Miller and Sooter (1967), this increase in size and weight translates into seed economy, reducing or eliminating the thinning, thus presenting a uniform stand. While Borderon (1989) and Sachs et al. (1982) state that the increase in size and weight, enables precision sowing. Roos and Moore III (1975) confirm the previous observations, emphasizing the possibility of mechanized sowing because the technique not only standardizes size and weight but also shape.

In addition to the above, seeds coated with bentonite, regardless of the treatment product used, were mostly retained in the 1.5 and 2.5 mm screen sieves, which is approximately 80% of the seeds. As for the seeds that were coated with gypsum or kaolin, 60% of them were retained in the 1.5 mm screen sieve. Again, this shows the superiority of the bentonite as a filling material, being able to add larger amount of material on the surface of the seed.

In relation to the porosity, the bentonite was superior to the other materials, increasing in 52% the porosity in relation to the bare seeds. The gypsum and the kaolin increased by an average of 38 and 22%, respectively, the pore size. The knowledge of this physical characteristic is important, especially in silos, where larger seeds, consequently with greater porosity, allow greater efficiency of the aeration and drying processes, due to letting the air, whether warm or not, pass more efficiently through the seeds. In addition, it reflects on fan sizing, drying and aeration systems and engine power (Silva and Corrêa, 2000). Thus, seeds coated with bentonite would require less air flow and consequently less energy.

As for the angle of repose of the seeds, only the fillers bentonite and gypsum modified the angle of the seeds, having the bentonite increased an average of 10 degrees and the gypsum increased 5 degrees the angle of repose of the seeds. However, different angles of repose between the materials are probably due to the characteristics of the filling materials, which provide coated seeds with different finish levels, consequently with different roughness at the end of the process.

Regarding the resistance of the coated seeds, the bentonite and the kaolin presented high resistances (up to 100%) with any treatment product. However, the gypsum exhibited low resistances, being the highest when it was used together with the fungicide (approximately 40%). This characteristic, as well as its size, is important when working with coated or pelleted seeds because according to Silva and Nakagawa (1998), the resistance is related to the maintenance of the integrity of the coated seed during the processing, transportation and handling operations. According to these same authors, the difference between the materials is due to the physical characteristics of the materials themselves, which for bentonite and kaolin formed firm structures with a certain plasticity, not breaking up after the fall, whereas for the gypsum formed a rigid structure without plasticity, causing the break of the coating with the impact due to the fall of the seed.

In general, the bentonite was shown to be a viable material for use in the colza seeds coating process, as it increases them in size, weight and gives resistance to the coating; all desirable characteristics in a coated seed. According to Silva and Ferreira (2008) bentonite is employed in the industry as a binding agent and binder. These characteristics are probably responsible for differentiating the bentonite from the other materials when used in the incrustation of colza seeds. As a way of validating the bentonite as a material capable of coating seeds, germination and vigor tests are required, since this material may retard/inhibit the germination.

Conclusions

In view of the above, it can be concluded that: Colza seeds coated with bentonite present greater diameter, number of times increased, porosity, angle of repose and weight of one thousand seeds, followed by gypsum and kaolin. Seeds coated with bentonite and kaolin are more resistant to the fall, whereas the ones coated with gypsum are less resistant. Seeds coated with bentonite are retained, for the most part, in 1.5 and 2.5 mm screen sieves. The gypsum and the kaolin used in the coating provide seeds that are mostly retained in 1.5 mm screen sieves. The treatment products exert little influence on the physical characteristics of the coated seeds. The combination of gypsum + fungicide increases the resistance of the coating.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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