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Development and Evaluation of a Prototype for Seed Coating

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Abstract

The use of technologies is increasingly present in agriculture. The seed coating is one of these technologies. However, to obtain it, it's demanded the use of machines and technics which are restricted to production companies, burdening the price on this type of product. Given the above, it was aimed to develop and evaluate a prototype capable of coating small seeds. To elaborate the conceptual design of the prototype it was employed the computer program for modeling 3D SketchUp, version 2014. The prototype measures were expressed in millimeters (mm). The prototype has three main parts: (1) support base, (2) seed coating bowl, and (3) cementing material container. To evaluate the prototype, bentonite, gypsum and kaolin were used as filling materials of the colza seed (*Brassica napus* L.). As cementing material the PVA glue was used in the percentages of 20, 30, 40 and 50%. The studied variables were prototype yield, production cost of the coated seeds and residue generated in the coating process. The prototype has a compact size, answering the needs of laboratory and/or small producer. It presented cost and residues in an acceptable level and yield up to 88%.

Keywords: seed coating machine, yield, production cost, residue, colza seed

1. Introduction

The agriculture since its emergence, about 10 to 15 thousand years ago until nowadays, went through several transformations. Initially, agriculture was directed towards the subsistence of the communities that planted them and also explored surrounding areas. However, over the years with the high population growth, it was necessary to increase production to supply the needs and meet the market demand, which eventually transformed the agricultural system (Santos & Nascimento, 2009).

The appearance of machinery and implements in the agriculture of the XIX century made gains possible in agricultural productivity and work, definitively changing the trajectory of production techniques and raising the offer of agricultural products in the world (Vian et al., 2013).

The modern systems of agricultural production converge quickly to precision agriculture, which requires improvement of cultivation systems, ensuring the technical and economic success of agricultural activities, providing an ideal establishment of plants per unit area, which favors not only cultivation but also mechanized harvest (Mahmood et al., 2013; Bernardi et al., 2014).

Despite the advances achieved with the emergence of agricultural machinery, there are some limitations on their part. One of these limitations is the use of small or irregularly shaped seeds in the mechanized planting, which hinders the correct regulation of seed distribution in the soil, thus causing waste of seeds or an irregular final stand (Queiroga & Silva, 2008).

Among the solutions proposed to remedy this production problem is the use of the seed coating technique. This technique consists in the application of inert or non-inert materials on the seeds, with the purpose of improving the planting distribution (Lopes & Nascimento, 2012).

One of the types of coating is inlaying/pelletizing, which consists in the coating of the seeds with a dry, inert material of fine granulometry (filling), a cementing material (adhesive) which must be water soluble and also covering and finishing materials. This treatment allows the seed to have a rounded shape, increasing its size and making its distribution easier, either by hand or by machine (Nascimento et al., 2009; Lopes & Nascimento, 2012).

For the composition of the coated/pelleted seeds, it is necessary to know the materials and techniques used in the process, which are inaccessible information along the companies that produce this seed line. In addition, specific equipment are necessary which are provided by a limited number of companies, which are generally international, without resale in the country, presenting a high cost, making it impossible for producers of family agriculture (Queiroga et al., 2009).

Therefore, the development of an alternative equipment that enables the coating of small seeds, presents low cost and it is easy to use would give producers a way to increase their profit margin. In view of the above, the objective of this work was to develop and evaluate a prototype capable of coating colza seeds at the laboratory and/or small producer level.

2. Methods

2.1 Place of the Prototype Development

The prototype was designed and developed at the Laboratory of Storage and Processing of Agricultural Products, Federal University of Campina Grande, at a workshop located in the industrial district of the county of Campina Grande, Paraíba, Brazil.

2.2 Prototype Schematization

Based on agricultural machines to produce pelleted seeds, it was employed the technique for project development suggested by Pahl and Beitz (1996), thus the seed coating prototype is composed of three main parts:

2.2.1 Support Base

In the base (12) is located the engine (11), which is responsible for the rotation of the bowl (02), and the dryer (14), which is responsible for decreasing the moisture when applying the covering mixture and the powders. The base was manufactured of steel sheets and painted with synthetic paint in order to facilitate cleaning and conservation. This base supports the bowl, where the seeds are coated. Still in the base, in the upper left side there is a hose (08) that is connected to the dryer and carries hot air into the bowl (Figure 1).

2.2.2 Seed Coating Bowl

The bowl (02) is located on the upper side, in the central part of the base, which is coupled to the engine (11) through an axis, it has a nut at the end, allowing the removal of the bowl for cleaning and replacement. Surrounding this bowl there is a cylindrical part that gives protection to the user when the prototype is in operation and also provides support to the bowl lid. In the lid (01) there is a funnel (07) and the mixture (03-15) and the dryer hoses (08) (Figure 1).

2.2.3 Cementing Material Container

The third part is the cementing material container (04), where the mixture is placed and carried into the bowl using an air pressure generated by a compressor. In the lid of the cementing material container there are two valves, where in one of them the air from the compressor enters, through a hose (05), forcing the cementing material to enter the tube connected to the second valve, which is connected to the hoses (03-15) that come into the bowl. Inside the bowl the cementing material is sprayed on the moving seeds using two spray nozzles (17) positioned opposite to each other. Still inside the bowl there is a disperser (18) responsible to disaggregate the seeds in rotation, exposing them to the hot air generated by the dryer (Figure 1).

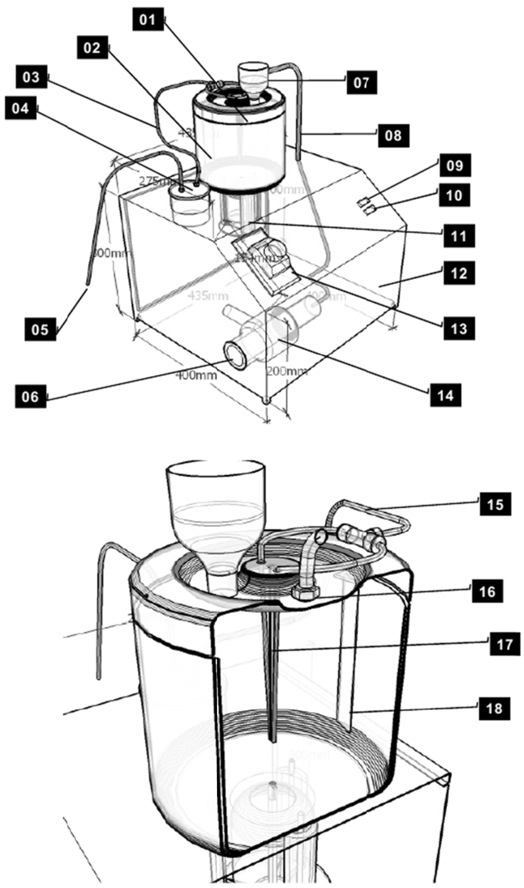

Figure 1. Isometric view of the prototype, longitudinal cut of the seed coating bowl and components of the prototype for seed coating

2.3 Electrical Components Specification

The rotating engine of the bowl has a power of 170 W, generating an approximate average consumption of power of 0.16 kW h^{-1}, working at 220 V. As for the dryer, it has a power of 1700 W, generating an average consumption of 1.7 kW h^{-1} and working at 220 V. This information has been taken from the manufacturer's manuals of each respective component.

2.4 Methodology for the Prototype Use

It was developed a methodology for the use of the prototype which includes the sequence of use of the prototype, from the addition of the seeds to the prototype until obtaining the coated seeds. This methodology was based on reports found in the literature, with modifications made in the prototype developed, according to Figure 2.

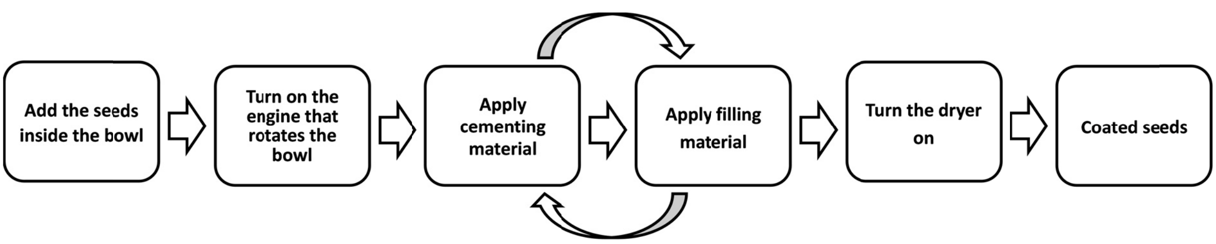

Figure 2. Operating flow of the prototype for seed coating of colza seeds (*Brassica napus* L.)

2.5 Prototype Evaluations

The prototype was evaluated in terms of yield, production cost and residue generated by the prototype with the filling materials bentonite, gypsum and kaolin and the PVA glue in the percentages of 20, 30, 40 and 50% in the mixture as cementing material. For this were used 150 g of filling material and 30 g of colza seeds (*Brassica napus* L.). By preliminary tests, the temperature of 50 ºC was adopted for the dryer and the coating bowl spinning in the rotation of 80 rpm. A digital tachometer was used to determine the rpm.

2.5.1 Prototype Yield

The yields of the prototype for seed coating, in the different filling materials and percentages of cementing material were determined according to Medeiros et al. (2004) using the Equation (1) below:

$$Y(\%) = 100 \times [WCS/(WBS + WFM + WCM)] \quad (1)$$

Where, WBS: Weight of the bare seed (g); WFM: Weight of the filling material (g); WCM: Weight of the cementing material (g); WCS: Weight of the coated seed (g).

2.5.2 Production Cost of the Seeds

The production cost of the seeds was calculated by the Equation (2) below, modified from Barros Neto et al. (2014). The values of the materials were obtained soliciting prices on the internet, through the average price of three suppliers. The power cost was obtained through the local power distribution company.

$$PC(R\$) = 1000 \times [(QBS \cdot C1 + QFM \cdot C2 + QCM \cdot C3 + E \cdot T \cdot C4)/QFCS] \quad (2)$$

Where, PC: Production cost of the seeds (R\$ kg^{-1}); QBS: Quantity of bare seeds(g); QFM: Quantity of filling material (g); QCM: Quantity of cementing material (g); E: Energy consumed in the process (kW h^{-1}); T: Time consumed in the process (h); C1: Cost of bare seed (R\$ kg^{-1}); C2: Cost of the filling material (R\$ kg^{-1}); C3: Cost of the cementing material (R\$ L^{-1}); C4: Cost of electricity (R\$ kW h^{-1}); QFCS: Final quantity of coated seeds (g)

2.5.3 Residue Generated in the Coating Process

The residue generated in the coating process was determined by the powder resulting from the screening of the seeds and scraping the bowl to remove the aggregated material in its walls. After this process, the residue was weighed in a precision digital scale and the result was expressed in grams.

2.6 Experimental Design and Statistical Analysis

The experiment was organized in a completely randomized design and disposed in a 3 × 4 factorial scheme (filling materials x percentages of cementing material). Each coating process was repeated four times. The data were submitted to Analysis of Variance ($P \leq 0.05$). For the quantitative factor, regression was used in the analysis of variance, generating models for each filling material. For the qualitative factor the means, when necessary, were compared by the Scott-Knott test ($P \leq 0.05$). For the statistical analyzes the software Assistat version 7.6 was used. In addition, the cost of production values were converted from Real to Dollar and presented in parentheses.

3. Results

The prototype for seed coating (Figure 3) is composed of three main parts: (1) support base, (2) seed coating bowl and (3) cementing material container.

Support base: The base is built in nº 18 steel sheet and industrial square tubes of 20 mm, giving the structure resistance. It has a compact size, answering the needs of laboratory and small producers. The base was painted with synthetic enamel paint to avoid rust and facilitate cleaning.

On the base are set the speed controller of the bowl's rotating engine and the dryer controllers. Also on the base is the cementing material container. Inside the base are set the dryer and the rotating engine of the bowl. The dryer is connected to the bowl by a hose (Ø = 3/8") which is attached to it using a quick-release valve (3/8"). On the left outer portion of the support base is a dryer exhaust outlet, allowing the entrance of cold air and exit of hot air through the hose.

Seed coating bowl: The bowl is made from a cylindrical aluminum container that has capacity of 2.5 L. Inside the bowl the cementing material is applied to the seeds by spray nozzles which are disposed opposite to each other to maximize the application. Inside the bowl there is a disperser which promotes the disaggregation between the seeds, allowing the filling and cementing materials to be more efficient. The bowl is fixed to the axis using a nut, making cleaning and replacement easy.

Cementing material container: The cementing material container is made of tempered glass (300 mL) and the lid of aluminum, where two valves (Ø = ¼”) are attached. In one of the hoses, the air generated by a compressor, at a pressure of 30 Psi, enters causing the liquid deposited in the container to be pushed through the other valve which secures the hose that carries the cementing material into the bowl.

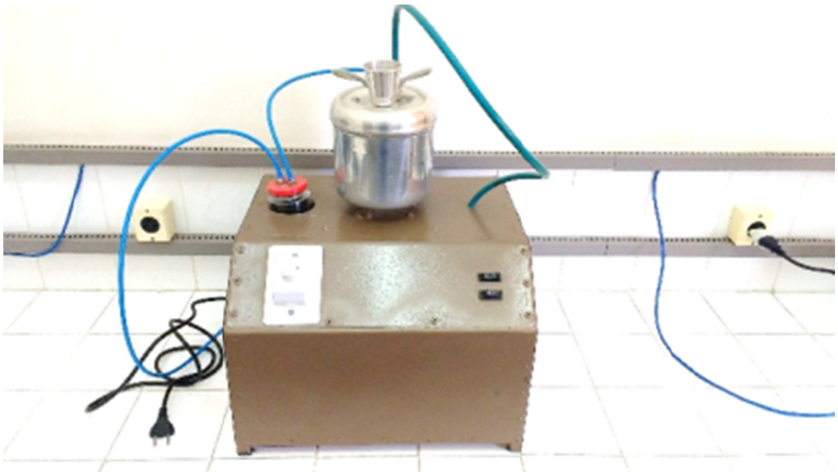

Figure 3. Prototype developed for seed coating

In Table 1 are the values of the mean squares relative to the prototype yield (R), total cost of production of coated seeds (CT) and residue generated in the coating process (RP); where it is observed a highly significant effect for the factors and their interactions.

Table 1. Mean squares regarding the yield (RY), total cost of production of the coated seeds (CT) and residue generated in the process (RP)

SF	DF	Mean Squares		
		Y	CT	RP
FM	2	2603.7763**	464.2216**	27631.5674**
PC	3	187.5847**	34.3320**	207.9501**
FM × PC	6	237.3282**	57.4494**	901.2712**
Error	36	4.1279	0.9189	7.9447

Note. ** significant at 1%. Filling materials (FM), Percentages of cement (PC).

It is observed that in percentage of 20, the highest yield was found when using the kaolin (68.08%), differing statistically from the yield verified when using the bentonite (59.11%), which presented an intermediate behavior. On the other hand, when gypsum was used, the yield was of 48.66%, being statistically different from the other materials and the lower yield for this percentage of cement used (Table 2).

For the percentages of 30, 40 and 50%, the highest yields were observed when using bentonite (76.95; 79.86 and 88.63%, respectively), presenting statistical difference of the kaolin (68.75; 62.54 and 63.78%, respectively), being this material the one that provided an intermediate yield. The gypsum differed statistically from the other materials, showing lower yield, with values varying from 62.54 to 68.75% (Table 2).

Table 2. Yield means (%) of the prototype for coating colza seeds (*Brassica napus* L.) with bentonite, gypsum or kaolin and percentages of PVA glue in the mixture

Filling Materials	Percentages of cement*			
	20	30	40	50
Bentonite	59.11±0.70 b	76.95±0.65 a	79.86±0.77 a	88.63±0.52 a
Gypsum	48.66±0.14 c	52.46±0.78 c	51.30±0.91 c	50.65±0.92 c
Kaolin	68.08±0.99 a	68.75±0.76 b	62.54±1.37 b	63.78±1.33 b

Note. * Means followed by the same lowercase letter in the column do not differ from each other by the Scott-Knott test ($P \leq 0.05$). CV (%) = 3.16.

According to the regression in the analysis of variance, the highest degree models that best fit the yield data in function of the percentage of cementing material in the covering mixture was of second degree for the bentonite and the gypsum, with coefficients of determination of 0.95 and 0.80, respectively. For the kaolin the highest degree model that best fit the experimental data was the first degree one, with coefficient of determination of 0.63. It is observed that for the bentonite there was an improve of yield with the increase of the percentage of cementing material in the mixture, with yield of approximately 60% when using the percentage of 20%, reaching a yield of approximately 90% when using the percentage of 50%. For the gypsum and the kaolin it is noticed that there was practically no increase of yield with the increase of the percentage of cementing material in the mixture. For the gypsum, when the percentage of 20% was used, there was a yield around 50%, and when the percentage of 50% was used the yield continued around 50%. For the kaolin, when the percentage of 20% was used, the yield was approximately 68%, with a slight drop reaching approximately 63% when using the percentage of 50% (Figure 4).

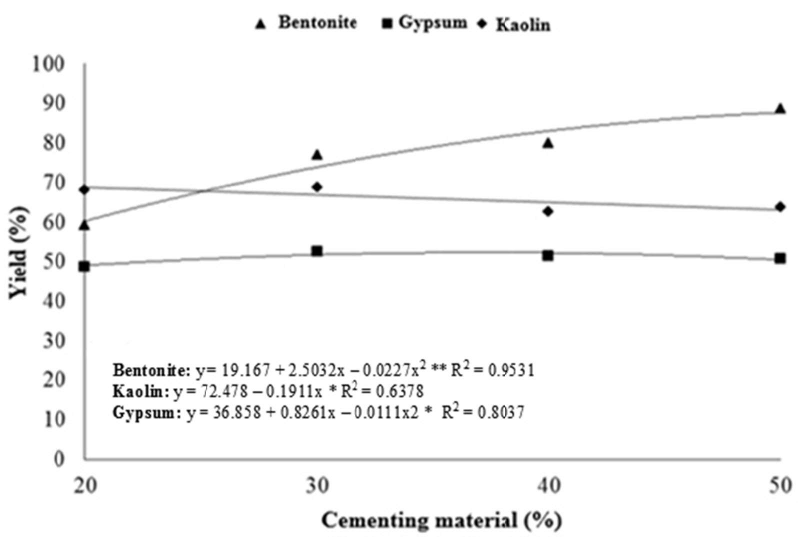

Figure 4. Yield (%) of the prototype for coating colza seeds (*Brassica napus* L.); with bentonite, gypsum or kaolin at the different percentages of PVA glue

It can be verified that the filling material and the percentage of cementing material influenced the prototype yield. It is noticed that the increase in the percentage of cement for the gypsum and the kaolin had little influence on the yield. On the other hand, the bentonite behaved differently, with an increase up to approximately 30% with the variation of the percentage of cement, obtaining the best yields (Table 3).

In the percentages of 20 and 30%, the gypsum presented the lowest production costs (23.62 and 22.19 R\$ kg^{-1}, respectively), differing statistically from the use of the kaolin (28 and 27.93 R\$ kg^{-1}, respectively). The bentonite, however, presented the highest production cost, with values varying from 32.62 to 42.32 R\$ kg^{-1} (Table 3).

For the percentage of 40%, the lowest production cost of the coated seeds was verified when using the gypsum (23.03 R$ kg^{-1}), differing statistically from when using the kaolin and the bentonite (30.92 and 31.61 R$ kg^{-1}, respectively), which were statistically the same (Table 3).

In the percentage of 50% the lowest production cost of the coated colza seeds was verified statistically when using the gypsum (23.50 R$ kg^{-1}) and the highest when using the kaolin (30.59 R$ kg^{-1}), with the bentonite having an intermediate cost (28.68 R$ kg^{-1}), according to Table 3.

Table 3. Means of production cost (R$ kg^{-1}) of the colza seeds (*Brassica napus* L.) coated in the prototype with bentonite, gypsum or kaolin and percentages of PVA glue

Filling materials	Percentages of cement*			
	20	30	40	50
Bentonite	42.32±0.54 a (11.38)**	32.62±0.27 a (8.77)	31.61±0.52 a (8.50)	28.68±0.58 b (7.71)
Gypsum	23.62±0.08 c (6.35)	22.19±0.33 c (5.97)	23.03±0.42 b (6.19)	23.50±0.45 c (6.32)
Kaolin	28.00±0.41 b (7.53)	27.93±0.26 b (7.51)	30.92±0.68 a (8.31)	30.59±0.65 a (8.22)

Note. * Means followed by the same lowercase letter in the column do not differ from each other by the Scott-Knott test ($P \leq 0.05$). ** Value in dollars is in parentheses (US$ kg^{-1}) CV% = 3.33.

According to the regression in the analysis of variance, the highest degree models that best fit the experimental data of production cost in function of the percentages of cementing material were first degree for the kaolin and second degree for bentonite and gypsum. For the bentonite, gypsum and kaolin the coefficients of determination were 0.94 and 0.72, 0.73, respectively. It is noticed that for bentonite, there was a decrease in the production cost when increasing the percentage of cementing material, with a cost of 42.32 R$ kg^{-1} when using the percentage of 20%, reaching a cost of 28.68 R$ kg^{-1} when using the percentage of 50% (Figure 5).

For gypsum and kaolin it is observed little change in the production cost when increasing the percentage of cementing material. For the gypsum, the cost to produce one kilogram of coated colza seed, when using the percentage of 20% was R$ 23.62. However, when using the percentage of 50% this value has hardly changed being of R$ 23.50. For the kaolin, a slight increase in the production cost can be observed with the increase of the percentage of cementing material in the mixture, being R$ 28.00 to 20% and R$ 30.59 when using the percentage of 50% (Figure 5).

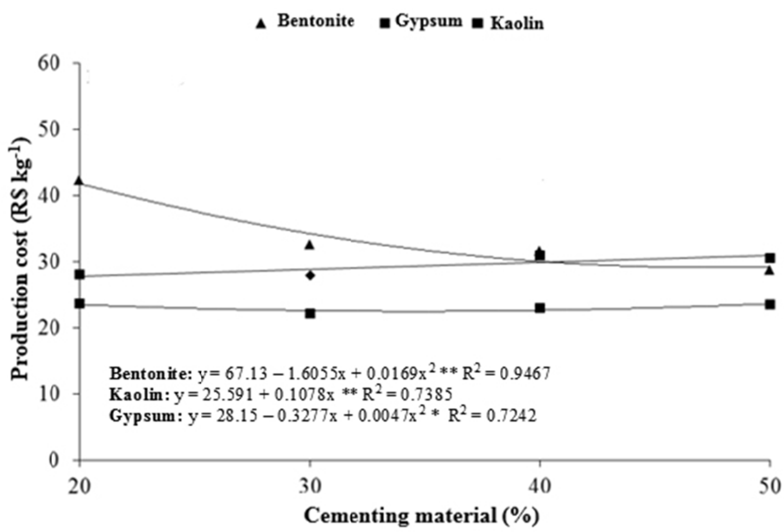

Figure 5. Production cost (R$ kg^{-1}) of the colza seeds (*Brassica napus* L.) coated with bentonite, gypsum or kaolin in the percentages of PVA glue

As for the production cost of the seeds, it is verified that with the bentonite, a decrease occurred with the increase of the percentage of cementing material. For the plaster and the kaolin, the production cost was little changed with the increase in the percentage of cementing material. It is expected that the cost will be reduced with the increase of the percentage of cement, since it is a function of the yield. That is, when the yield increases, a smaller amount of filling material is needed to obtain seeds of the desired size. Just as in the yield, little the cost has changed for the gypsum and kaolin. The production cost among the materials were different because they were a function of the yield, but also because they presented filling materials with different costs, which made the gypsum present lower cost despite having a low yield. Similar behavior occurred with the kaolin (Table 4).

In general, it can be observed that the highest residue was found when using the kaolin, which had values ranging from 123.76 to 138.48 g. The kaolin was statistically different from the gypsum, which presented the second higher residue, with values varying from 92.19 to 103.43 g. The bentonite, among the three filling materials, was the one that presented the lowest residue and differed statistically from the other two filling materials. For the bentonite the residue values ranged from 30.61 to 77.71 g (Table 4).

Table 4. Means of the residue (g) generated in the coating process of colza seeds (*Brassica napus* L.) in the prototype with bentonite, gypsum or kaolin, and percentages of PVA glue in the mixture

Filling materials	Percentage of cement*			
	20	30	40	50
Bentonite	77.71±0.98 c	45.12±0.95 c	39.62±0.15 c	30.61±0.28 c
Gypsum	92.19±0.53 b	93.31±1.22 b	99.42±0.50 b	103.43±0.50 b
Kaolin	123.76±0.31 a	125.61±0.31 a	135.84±0.42 a	138.48±0.29 a

Note. * Means followed by the same lowercase letter in the column do not differ from each other by the Scott-Knott test ($P \leq 0.05$). CV% = 3.06.

According to the regression in the analysis of variance for the bentonite, the highest degree model that best fit the experimental data of the residue as a function of the percentages was the second degree one, with coefficient of determination of 0.95. On the other hand, for the gypsum and the kaolin, the models that best fit were first degree ones, with, with coefficients of determination of 0.92 and 0.64, respectively. With the bentonite it can be observed that there was a decrease of the residue at the end of the process when increasing the percentage of cement in the mixture. At the lower percentage (20%) of cement, for this material, the residue was 77.71 g, occurring a decrease in that quantity, reaching 30 g when using the highest percentage of cement (50%) (Figure 6).

When using the gypsum as filling material, a slight increase in the residue was observed with an increase in the percentage of cementing material, being 92.19 g for the percentage of 20% and 103.43 g for the percentage of 50%. The kaolin had a similar behavior to the gypsum, with a slight increase in the residue with an increase in the percentage of cementing material. When the percentage of 20% was used, the mean residue was 123.76 g, reaching 138.48 g when using the percentage of 50% of cementing material in the mixture (Figure 6).

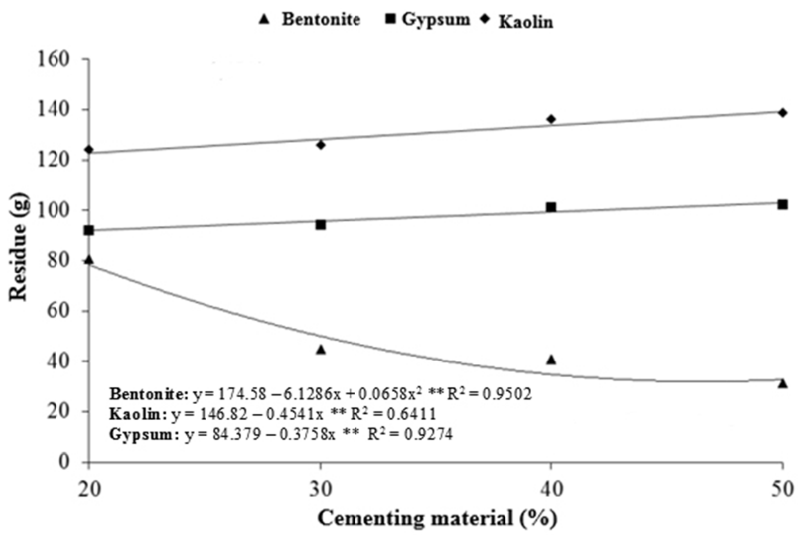

Figure 6. Residues (g) generated in the process of coating colza seeds (*Brassica napus* L.) with bentonite, gypsum or kaolin at the different percentages of PVA glue in the covering mixture

4. Discussion

In relation to the residue it's seen that the bentonite among the three materials interacted more efficiently with the cementing, presenting the lower residues. It's also seen that with the bentonite the increase in the percentage of cementing material provided a reduction of the residue, showing compatibility between the cementing and the filling material. The gypsum and the kaolin presented a slight increase of the residue with the increase of cementing material, unlike the bentonite which had a visible reduction of residue with the increase of the cementing percentage.

In general, the prototype for seed coating presented satisfactory results with the colza seeds, reaching yields up to 88% when using the bentonite combined with the PVA glue to 50%. Regarding the production cost of the seeds, the machine again showed good results producing coated seeds with values ranging from 23 to 42 R$ kg^{-1} being affordable to family farming. In a general way, the machine developed in this work was able to achieve the goals for which it was conceived, and could be spread to small communities and rural associations. In order to complement this study, it is necessary the evaluation of this machine for small seeds of other species, that have different shapes, weights and surface characteristics other than that studied in this work.

In relation to the evaluated parameters of the prototype it is verified that it presents satisfactory performance with yield up to 88% being in agreement with the results obtained by Medeiros et al. (2004), who evaluated a prototype for seed covering using carrot seeds, vermiculite (filling) and PVA glue(cementing), obtained yields varying from 77.3 to 88.7%.

The bentonite stood out for all variables studied, showing greater compatibility with the cementing material used. Thus, for the prototype the bentonite is the most suitable material for use in the coating process. The final choice of the filling material should still involve evaluations of physical and physiological characteristics of the seeds.

This is an important aspect, considering that the materials present different levels of compatibility between themselves. Mendonça et al. (2007) verified similar behavior, when the authors working with different filling and cementing materials observed aggregation levels of the filling material varying according to the combination used.

In general, the prototype developed in this work was able to achieve the goals, and could be taken to small communities and rural associations; also it can be tested for small seeds of other species that have different shapes, weights and surface characteristics other than that studied in this work.

5. Conclusions

In view of the above, it can be concluded that: the designed and developed prototype is functional and capable of coating colza seeds (*Brassica napus* L.); the prototype presents satisfactory performance, with yield up to 88% and cost of the seeds up to 42 R$ kg^{-1}.

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