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Physiological Quality of Cabbage (*Brassica oleracea* (L.) var. capitate) Seeds Coated with Different Materials

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***Abstract*— *The seed coating technique has driven the development of the seed industry that seeks to offer a competitive product; it has improved the characteristics of planting, germination, vigor and sanity of the seeds, especially those with very small sizes that make it difficult to manipulate, as observed in vegetable seeds. However, information on aggregating materials is still very restricted to large companies. The objective of this study was to evaluate the physiological quality of cabbage seeds (Brassica oleracea (L.) var. Capitata) coated with bentonite, gypsum and kaolin and different percentages of gum arabic. The coating was performed using as filler materials, bentonite, gypsum and kaolin and as cementing material gum arabic in the percentages of 20, 30, 40 and 50%. The coating of the seeds was made in a design developed equipment for this purpose. After coating, the seeds were submitted to germination and vigor tests and the water content was also determined. The experiments were organized in a completely randomized design, in a factorial scheme 4 x 4 (fillers and percentages binder). Data were submitted to Analysis of Variance by the F test ($p \leq 0.05$) and the means, when necessary, compared by the Skott-Knott test ($p \leq 0.05$). The coating with gypsum promoted the highest values for most of the studied variables, not differing in some cases from the non-treated seed, followed by kaolin and bentonite. The cementing material contributed to the difference between the variables, where the highest levels were responsible for low germination and vigor of the seeds.*

***Keywords*— Brassica oleraceae. Germination. Seed Coating Vigor.**

I. INTRODUCTION

The summer cabbage (*Brassica oleracea* L. var. *capitata* L.), is a widely acclimated and easy-to-grow vegetable that has been prominent in the diet of the population due to its high nutritional value, and source of important amounts of vitamins and minerals (Filgueira, 2012). In Brazil, the production of vegetables has great economic relevance, presenting an important socioeconomic role by the high demand of labor (HÖLBIG et al., 2010). In order to meet this demand, it is necessary to study new techniques and/or methods, or to improve the already existing ones, that can be used in the seed production fields, aiming higher yields, quality and profit.

In this scenario, seed coating is a practice that improves size characteristics of the seeds, making the operations involved during sowing less limited. This practice consists in the formation of a small capsule around the seed resulting from the aggregation of powders and liquids added alternately or simultaneously in a rotating drum (GADOTTI and PUCHALA, 2010; QUEIROGA et al., 2012).

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Coating also reduces labor during manual seed distribution, facilitates the adoption of mechanized techniques in sowing and can contribute to the elimination of the thinning practice of excess of plants (SILVA et al., 2002). For this, studies are necessary to provide information to a protocol of analysis of coated seeds, since the basis for such tests are performed on uncoated seeds (GIMÉNEZ-SAMPAIO and SAMPAIO, 2009).

Despite the advantages involved in coated seeds, there is a lack of studies on this subject, besides the lack of specific information about materials that can be used as fillers and cementing material. Based on that, the objective was to evaluate the physiological quality of cabbage (*B. oleracia* var. Capitata) seeds coated with different types of fillers and percentages of cementing material.

II. MATERIAL AND METHODS

This study was carried out at the Laboratório de Armazenamento e Processamento de Produtos Agrícolas (LAPPA) of the Universidade Federal de Campina Grande (UFCG), Campina Grande- Paraíba, and at the Laboratório de Análise de Sementes (LAS), of the Department of Fitotecnia e Ciências Ambientais (DFCA) of the Universidade Federal da Paraíba (UFPB), Areia-PB.

Seeds of Cabbage (*B. oleracia* var. Capitata), without pesticides, were purchased from ISLA Sementes LTDA. As filler material, bentonite, gypsum and kaolin waste were used as powder in fine granulometry, and gum arabic Super Radex in the liquid form was used as a cementitious material. For the preparation of the different percentages of cementing material, 20, 30, 40 and 50 mL of gum arabic diluted in 80, 70, 60 and 50 mL of distilled and sterilized water (ADE) were used, respectively, obtaining the percentages of 20, 30, 40 and 50%. The homogenization was performed in a beaker with the aid of a spatula.

The coating of the seeds was carried out in a machine developed by LAPPA especially designed for this purpose. Thirty grams of cabbage seeds were coated for each percentage of cementing material, applying the filler in the seeds in ten 15 grams portions, totaling 150 grams of filler. The seeds were placed inside the recipient of the prototype, which rotated at approximately 40 rpm. As the container rotated, the materials were added and, alternately, the cementing material (different percentages) were applied with the aid of a 20 ml mini-spray. The seeds were then placed in plastic trays lined with paper towel and placed to dry under shade for four days.

The variables evaluated were: water content - the uncoated and coated seeds were placed in a greenhouse regulated at 105 ºC ± 3 ° for 24 h, using four replicates of 1 gram (BRASIL, 2009); percentage of germination - four replicates of 50 seeds were used and the treatments were arranged in a B.O.D. regulated at an alternating temperature of 20-30 ° C, in a photoperiod of 8 hours and 16 hours dark. Seeding was carried out in gerboxes (11 x 11 x 3.5 cm - length, width and depth, respectively) containing as substratum two sheets of blotting paper and a third sheet of germtest paper of similar size to cover the seeds. The substrate was moistened with distilled water in a volume equivalent to 2.5 times its dry weight and counts were performed five and twelve days after the start of the test (BRASIL, 2009). The percentage of normal seedlings was calculated according to the formula proposed by LABOURIAU and VALADARES (1976).

First germination counting was performed by counting the normal seedlings on the fifth day after sowing; at the time of the germination test the accumulated percentage of normal seedlings was counted at five days after sowing; shoot dry matter - at the end of the germination test, the shoots of the normal seedlings of each treatment and replicates were conditioned separately in Kraft paper bags, identified and taken to the stove regulated at 65 °C for 48 hours. After this period they were weighed in an analytical scale, with an accuracy of 0.001g and the results expressed in milligrams.

Statistical analyses were performed with the software Assistat version 7.6 (SILVA and AZEVEDO, 2009). The experiments were organized in a completely randomized design (CRD), arranged in a 4 x 4 factorial scheme (fillers x percentage of cementing material), with four replicates of 50 seeds. Data of water content observed before and after the accelerated aging were submitted to analysis of variance by the F test ($p \leq 0.05$) and the Scott-Knott test ($p \leq 0.05$) was applied to the filler materials and regression in the analysis of variance for the percentages of cementing material.

III. RESULTS

It cn be observed on Table 1, a highly significant effect for the isolated and interacting factors, thus revealing statistical differences among the means.

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Table 1. Average squares for germination (G), first germination counting (FC), shoot dry matter weight (SDMW) and accelerated aging (AA) of seedlings from cabbage seeds (Brassica oleracia var. Capitata) encrusted with different filling materials (FM) and percentage of cementing material (CM)

Source of variation	Mean Square				
	DF	G (%)	FC (%)	SDMW (mg)	AA (%)
FM	3	4401.354**	69855.292**	0.23315**	687.354**
CM	3	3278.438**	3513.042**	0.07258**	550.854**
FM x CM	9	136.063**	775.139**	0.07373**	89.757**
Error	48	6.0313	8.594	0.10539	20.292
CV (%)		3,28	4,60	7,77	6,23

(**) Significant at 1% of probability

Based on Fig. 1A, data of percentage of germination of normal cabbage seedlings presented quadratic adjustment for bentonite and kaolin coating and linear for gypsum, both with different percentages of the cementing material (20, 30, 40 and 50 %), which showed a tendency of decrease in the viability of the seeds with the increase of the dose, this decrease was more evident from the dose of 30%, when a decrease in the percentage of germination was observed, indicating loss of physiological quality of the seeds. For the seeds not submitted to coating, the percentage of germination was 90.5%, and, with gypsum plus 20% of cementing material, the percentage was 95.5.

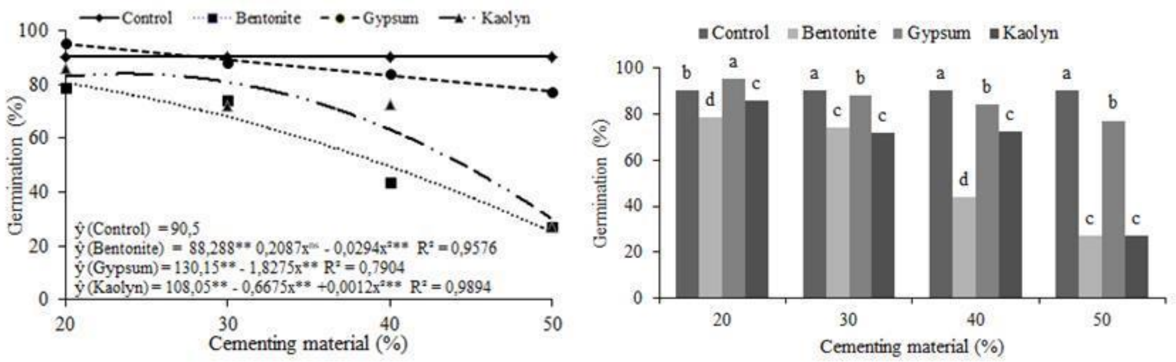

Fig.1: Germination (%) of cabbage seeds (Brassica oleracia var. Capitata) uncoated and coated with different fillers and percentage of cementing material

Comparing the germination of cabbage seeds (*B. oleracia* var. Capitata) coated with different fillers and percentage of cementing materials (Fig. 1), it can be observed that the percentage of 20%, gypsum promoted the greater germination (96%), statistically differing from the control (91%), kaolin (86%) and bentonite (79%), which presented the lowest germination among the tested materials in this percentage of cementing material. The lowest germinations were observed with the use of 50% of cementing material, with values of 27% for the seeds coated with bentonite and kaolin waste. The other percentages of cementing material promoted intermediate results, with statistical differences for all materials within the percentages of 30 and 40% of cementing material.

The regression curves of the first germination counting of cabbage seeds (*B. oleracia* var. Capitata) coated with bentonite, gypsum, kaolin and different percentages of cementing material are shown in Fig. 2. In relation to the control, no statistical significance was found, thus, the mean point (81%) was presented. It can also be observed that the gypsum treatment associated to the cementing material in the doses of 20 to 40% favored the germination of the seeds, with a superior response when compared to the control. For all the materials the initial germination decreased with the increase of the percentage of the cementing material. The decrease was most accentuated, especially for the seeds coated with bentonite and kaolin waste.

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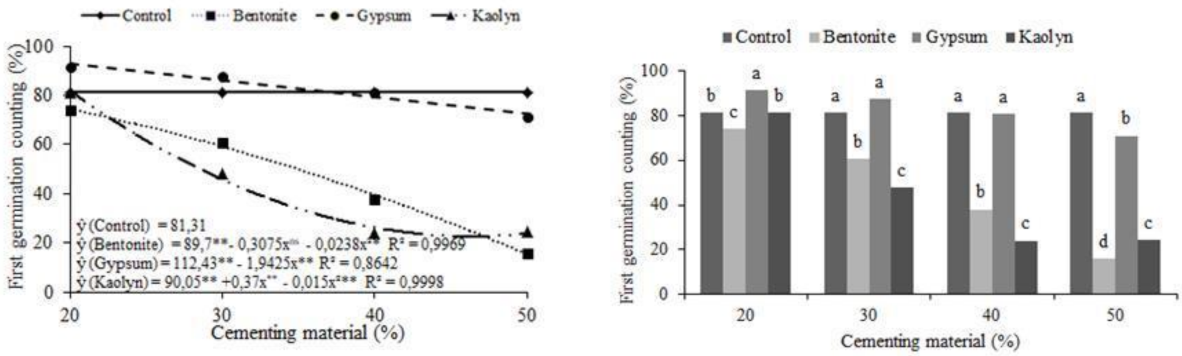

Fig.2: First germination counting (%) of cabbage seeds (Brassica oleracia var. Capitata) coated and uncoated with different filler materials and percentage of cementing material

Comparing the filler materials in each percentage of cementing material (Fig. 2B), it can be observed that there was no negative effect on the first germination counting for the lowest percentage of gum arabic. Therefore, in the percentage of 20%, the highest germination was observed with the gypsum (92%), differing statistically from those presented by the uncoated seeds and kaolin waste, both with 81%, statistically equal. On the other hand, the lowest germination was observed when bentonite was used (74%), differing statistically from the other materials.

Using the percentages of 30 and 40%, uncoated and gypsum coated seeds had the highest germination, with values of 81 and 85%, respectively. In the first germination counting, an intermediate behavior was observed in relation to the other filling materials, when bentonite was used, with germination values of 61 and 38% for the percentages of 30 and 40%, respectively. In the percentage of 50% of cementing material, the lowest value for germination was observed on seeds coated with bentonite (16%) (Fig. 2B).

For the dry matter of shoots of seedlings of seeds coated with the different materials, it can be seen a quadratic adjustment only for the seeds coated with bentonite (Fig. 3A). At the dose of 30%, the highest vigor 1.28 mg was recorded, and the lowest was recorded in the percentage of 50% with 0.73 mg when compared with the other treatments. Despite bentonite, it was verified that this variable was not significantly influenced by the increase of the percentage of gum arabic, when the materials used in the coating process were gypsum and kaolin waste, being presented the mean points of 0.894 and 0.844, respectively.

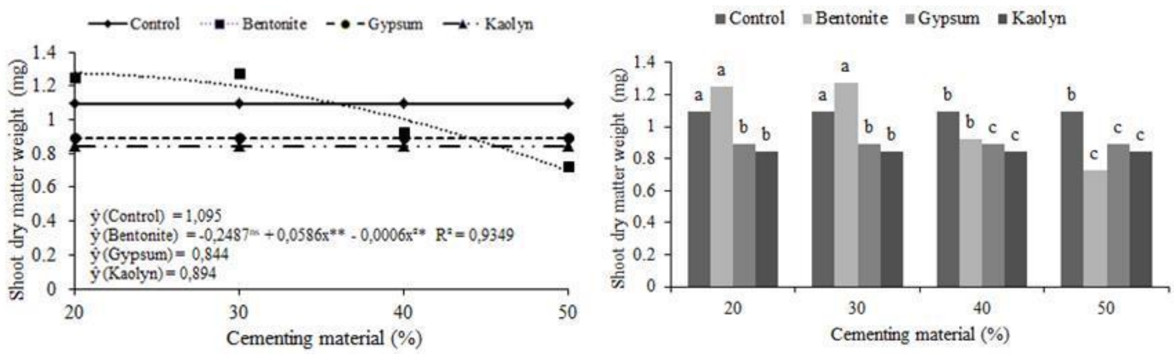

Fig.3: Dry matter of shoots (mg) of cabbage seedlings (Brassica oleracia var. Capitata) of uncoated and coated seeds with different fillers and percentages of cementing material

The highest dry matter of shoots values were recorded when using bentonite and the percentages of 20% (1.25 mg) and 30% (1.28 mg) of gum arabic. The filler materials of gypsum and kaolin waste at all doses of cementing material (20, 30, 40 and 50%) were found to be negatively influenced (Fig. 3B). For these coating materials there was no statistical difference, thus, the mean value observed was 0.84 and 0.89 mg, respectively.

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However, the bentonite within each percentage of cementing material was promising until the 30% dose, but in the percentage of 50% the lowest value of dry matter of shoots 0.73 mg was obtained.

The seeds used in the experiment had initial water contents of 7.5, 9.5, 5.5 and 4.2% for the control, bentonite, gypsum and kaolin waste, respectively (Table 2). It was observed an accentuated change in the water content of the coated and uncoated seeds, before and after accelerated aging.

Cabbage seeds coated with bentonite and kaolin waste, presented higher mean water content as the percentage of cementing material increased. The seeds coated with the gypsum in the different doses of cementing material, varied with less intensity in the water content, when compared to the other treatments (Table 2).

Table 2. Means of initial and final water content after accelerated aging of cabbage seeds (Brassica oleracia var. Capitata) with different fillers and percentage of cementing material

Filler material	Cementing material (%)							
	20		30		40		50	
	Initial	Final	initial	Final	initial	Final	initial	Final
Control	7.5	24.8	7.5	24.8	7.5	24.8	7.5	24.8
Bentonite	9.5	20.5	10.1	23.2	10.6	25.5	16.0	37.0
Gypsum	5.5	15.8	6.8	16.6	7.3	16.7	13.8	23.4
Kaolin waste	4.2	17.7	4.3	20.1	6.2	22.2	12.7	24.1

The germination values obtained after the accelerated aging test (Fig. 4A) in cabbage seeds (*B. oleracia* var. Capitata) presented linear models for the data resulting from the germination of seeds coated with gypsum and kaolin waste, and quadratic model for the values from seeds coated with bentonite.

After the aging test, the germination tended to decrease in order of higher impact for encrusted the seeds with bentonite, kaolin reject and gypsum with the increase of cementing material concentration, this decrease was not significant for the incrustation with gypsum. For the bentonite, a decrease in germination was observed with subsequent stabilization from the application above 30% of cementing material (Fig. 4A).

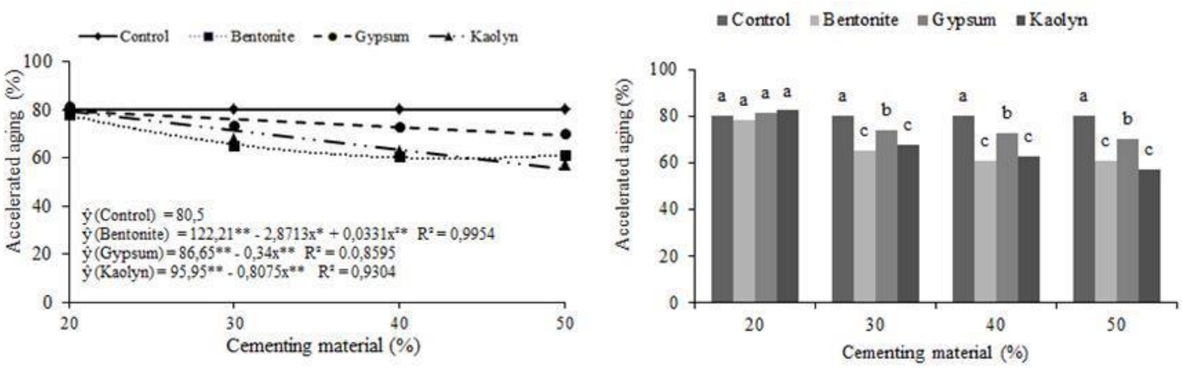

Fig.4. Accelerated aging (%) of cabbage seeds (Brassica oleracia var. Capitata L.) uncoated and coated with different fillers and percentages of cementing material

The highest percentages of germination were verified with the use of 20% of cementing material, with values of 78.25, 81.5 and 82.5% for the seeds coated with bentonite, gypsum and kaolin waste, respectively. The other percentages of cementing material did not differ statistically between bentonite and kaolin waste, both presented inferior vigor when compared to gypsum (Fig. 4B).

IV. DISCUSSION

In this study it is important to report the observations obtained regarding the size and the resistance of the seeds after coating (Data not shown). Significant differences were found in their size, both in relation to the filler material and the concentration of the cementing materials, as well as differences in the resistance of the aggregated material. The bentonite was the most consistent and larger than the other fillers used. The gypsum presented larger size in comparison to the kaolin waste, but both were less resistant, specifically in the lower concentrations of cementing material.

The highest percentages of germination were verified when gypsum was used, followed by kaolin and bentonite (Fig. 3). In addition, there was no negative effect on final germination for the lowest percentage of gum arabic (20%). In tomato seeds (*Solanum lycopersicumn* L.) coated with polymers there was also no change in physiological potential (Melo et al., 2015). However, the polymer used for coating of these seeds compared to the coatings used in this work form a thin film, therefore, a smaller barrier for the seed to interact with the medium. For this, small seeds such as carrots, *Daucus carota* L. (HÖLBIG et al., 2010) and coated seeds of the genus *Panicum* (BRITE et al., 2011), obtained high percentage of germination. However, on coated seeds of the hybrid *brachiaria* cv. Mulato II, was verified a decrease of viability and physiological potential (FERREIRA et al., 2015).

When cabbage seeds (B. oleracia var. Capitata) were submitted to coating with bentonite, there was a decline in germination (Fig. 1), this can be explained by the high viscosity attributed to the material, since the high water absorption capacity of the clay and its low permeability, when moistened, forms a viscous gel that expands its volume causing greater resistance to flow (BARBOSA et al., 2007; JAMES et al., 2008; MENEZES et al., 2009, TONNESEN et al., 2012).

Although the germination of bentonite-coated seeds in comparison to the other materials was lower, it gives good expectations for coating of cabbage seeds, because of the high percentage of germination at 20 and 30% gum arabic doses when compared to the others cementing materials (Fig. 1). However, it requires more studies that combine size, resistance and high quality. The methodology used by SILVA et al. (2002), having bentonite as cementing material combined with polyvinyl acetate for coating of lettuce (*Lactuca sativa*) seeds with microcellulose and fine sand did not affect negatively the final percentage of germination.

The percentage of germination was higher than the control in the seeds coated with the gypsum plus 20% of cementing material. This result may have been influenced by the low resistance and outcome of both during the coating process, as well as the ease of disaggregation when handling the seeds (Fig. 1). Another aspect to be considered is the properties of gypsum, rich in calcium sulfate, an important element in the root development of some crops, particularly by the correction of saturated soils by aluminum. As verified by ROCHA et al. (2008) the gypsum applied to the soil increased the yield of sugarcane crop. In this sense, the coating with gypsum tends to favor the seed in detriment of these characteristics.

The kaolin waste is a viable alternative of coating to be incorporated in this activity. In addition to the environmental appeal, there is a prospect of adding greater value to the product, since the results obtained in this work showed an excellent response for first germination counting and vigor after accelerated aging in cabbage (*B. oleracia* var. Capitata) seeds.

Based on the results of the first germination counting (Fig. 2) it can be observed that the coating delayed the initial germination process of the seeds with lower percentage of germination in comparison to the uncoated seeds, which occurred as there was an increase in the percentage, especially at the dose of 50%. These results are in accordance with PIRES et al. (2004) and SILVA et al. which found a decrease in the germination of bean (*Phaseolus vulgaris* L.) and lettuce (*L. sativa*) seeds as a function of the pelleting process, but not in the percentage of germination. Similar results were reported in pelleted seeds of *Nicotiana tabacum* L. (CALDEIRA et al., 2016).

The coating material, as well as the characteristics of the integument of each species, may have negative effects on the viability of the seeds (TRENTINI et al., 2005; EVANGELISTA et al., 2007). It also means a greater barrier to the gas exchange between the seed and the medium, modifying the permeability of the integument and consequently causing delay in germination when compared to the control (COSTA et al., 2001; WILLENBORG et al., 2004).

The use of bentonite as filler, provided a higher accumulation of dry mater, surpassing the control. The coatings with gypsum and kaolin waste, did not present significant differences for dry matter production (Fig. 3). A similar result was obtained by HÖLBIG et al. (2010) in carrots, (*D. carota*) coated with polymer.

The water content of the coated seeds tended to increase as a function of the cementing percentages. Therefore, the higher the percentage of gum arabic in the aggregation of the filler material, the higher the water content was (Table 2). For the bentonite material this relation was even greater, certainly, this occurred due to the high solubility of it, conferring maximum fixation of the filler material, thus, a larger area of contact to retain water. Studies on lettuce (*L. sativa*) and maize (*Zea mays* L.) showed that variations in the size of these seeds as a function of the coating and the percentage of cementing material, which causes a physical barrier, affect water absorption (SILVA et al. CONCEIÇÃO and VIEIRA, 2008).

Carrot seeds (*D. carota*) coated with vermiculite and fungicide had their water content very high after the process, which went from 7.8% to 23.5% (MEDEIROS et al., 2006), which is very high compared to the present work. Still according to the same authors, under these conditions it is necessary to proceed with drying in a stationary dryer.

The water content in seeds coated with gypsum and kaolin waste were very low up to the percentage of 40% of cementing material (Table 2). This indicates that this material contributed to dehydrate and delay the water absorption by the seeds before and during accelerated aging. Seeds of lettuce (*L. sativa*) pelleted had 3.1% of water content, and according to CORASPE et al. (1993) the pellet probably interfered in the calculation of this determination, consequently in its results.

In this sense, DERRÉ et al. (2013) states that the pelletizing forms a barrier around the seed, which confers slow absorption of water by the seeds, and causes a restriction to germination. Thus, the water content at adequate levels is indispensable for the seeds to trigger their metabolic process, which influences both the percentage and the speed, and uniformity of the germination process, as mentioned by MARCOS FILHO (2015).

It was also verified by the results of the accelerated aging test (Fig. 4A), that there was influence only by the cementing materials, since the seeds coated with bentonite, gypsum and kaolin waste presented an accentuated decrease of vigor in the higher levels of cementing material. This test allowed to separate the treatments in levels of vigor corroborating with the initial evaluation of quality. For CORASPE et al. (1993) only the accelerated aging test was efficient in identifying significant differences in the quality of pelleted lettuce (*L. sativa*) seeds.

It can also be verified that the differences in quality between the coated and uncoated seeds within the percent of cementing material of 20% according to Fig. 4B did not differ. Indicating that this concentration of cementing material did not negatively affect the germination of the seeds. Better germination performance after accelerated aging was also obtained by MEDEIROS et al. (2006) in pelleted carrot seeds (*D. carota*).

V. CONCLUSIONS

The physiological potential of coated cabbage seeds (*Brassica oleracia* var. Capitata) is influenced by the percentage of cementing materials;

The applied tests allowed to classify the cabbage (*B. oleracia* var. Capitata) seeds coated with gypsum, kaolin and bentonite and with different percentages of cementing material (20, 30, 40 and 50%) in levels of vigor;

Coating of seeds with gypsum plus 20% of gum arabic does not interfere the germination and vigor of the cabbage seeds (*B. oleracia* var. Capitata);

The bentonite aggregates satisfactorily during the coating process to the seeds and can be used for coating of cabbage (*B. oleracia* var. Capitata) seeds;

Bentonite requires further studies that may improve its permeability in order to be used as a filler.

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