POLYMER COATING, GERMINATION AND VIGOR OF BROCCOLI SEEDS

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ABSTRACT: *Brassica oleracea* var *italica* occupies a special place in the internal and external market of vegetables seeds. Vegetables producers demand seeds with high degree of purity, germination and vigor, since seeds' quality is the basis for the success of the production. In this work, broccoli seeds were coated in a spouted bed, by an aqueous suspension of hidroxy-ethyl-cellulose. Effects of the operating variables: spouting air temperature, atomizing air pressure and coating suspension flow rate over the dependent variables: seeds germination, seeds accelerated aging and the speed of seeds germination in soil, were investigated in a factorial scheme trial. The maximum processing time was 120 min. A totally randomized experiment evaluated and compared seeds germination and vigor of the coated and non-coated seeds. There was no identifiable, pronounced difference on germination of coated and non-coated seeds, accelerated aging of seeds, and speed of seeds germination in the soil. Coating with hidroxy-ethyl-cellulose in the spouted bed did not alter broccoli seeds physiologic quality. The surface of coated seeds presented satisfactory distribution and spreading of the polymer film, uniform and individual coating and homogeneous aspect.
Key words: hydroxyl-ethyl-cellulose, seed coating, spouted bed

RECOBRIMENTO POLIMÉRICO, GERMINAÇÃO E VIGOR DE SEMENTES DE BRÓCOLOS

RESUMO: Dentre as sementes de hortaliças comercializadas no mercado interno e externo, a *Brassica oleracea* var. *itálica* ocupa lugar de destaque. Os produtores de hortaliças têm exigido sementes com alto grau de pureza, germinação e vigor, uma vez que a qualidade das sementes é considerada a base para o sucesso do sistema de produção. Neste trabalho foi avaliado o recobrimento de sementes de brócolos em leito de jorro, utilizando uma suspensão aquosa de hidroxi-etil-celulose. Através de um planejamento fatorial completo de três fatores e dois níveis, determinou-se quantitativamente o efeito das variáveis operacionais: temperatura do ar de jorro, pressão de atomização e vazão de suspensão, sobre as variáveis dependentes: poder de germinação, envelhecimento acelerado e velocidade de germinação em solo. O tempo máximo de processo foi de 120 min. Um delineamento inteiramente casualizado foi aplicado para as mesmas variáveis dependentes, neste caso, avaliando diferenças entre sementes recobertas e não recobertas. Não houve diferença pronunciada na germinação, envelhecimento acelerado das sementes e velocidade de germinação em solo entre sementes recobertas e não recobertas. É possível recobrir sementes de brócolos com hidroxi-etil-celulose, em leito de jorro sem prejuízo à qualidade fisiológica das sementes. A superfície das sementes recobertas apresentou distribuição e dispersão satisfatória do polímero, recobrimento uniforme e individual e aspecto homogêneo.
Palavras-chave: hidroxi-etil-celulose, recobrimento de sementes, leito de jorro

INTRODUCTION

The seed coating process involves all aspects of sticking materials onto the surface of seeds. The term "coated seed" has been applied to a seed, which was either pelleted, coated or covered with an adhesive film. Such procedures are adequate for about 90% of small seed species. The costs and benefits of the coating procedure should be evaluated prior to selecting the seeds for the operation. Some seeds, of high aggregated value, like hybrid flower seeds, usually obtained in small amounts, should never be coated because the risks involved with the process may far exceed the benefits (Taylor & Harman, 1990). On the other hand, for many species of seeds, the coating process is worthy to be applied, with consequent improvement on the seeds quality and maintenance of properties after storage.

The germination of *Brassica napus* L. seeds was analyzed by Drew (1989), after being fluidized. Seeds, which were fluidized for 40, 60 and 180 minutes at 40°C had their capacity to produce normal seedlings decreased. For fluidization times above 30 minutes at temperatures above 35°C the germination was significantly dwindled. This behavior was attributed to the seed sensitivity to mechanical attrition and thermal exposures, which is an intrinsic characteristic of each species. The moisture content could be a problem to the seed when it reaches very low values, because this increases the seed sensitivity to mechanical damages.

The advantages of the spouted bed, over the rotating drum, were listed by Liu & Litster (1991): seeds do not agglomerate; seeds can be simultaneously dried and coated; coating is uniform; the equipment is mechanically simple with no moving parts. The aim of this work was to determine possible changes in the physiologic quality of broccoli seeds submitted to coating with aqueous suspension of hidroxy-ethyl-cellulose (HEC), as well as to assess the coating quality concerning homogeneity and uniformity with purpose of giving maintenance to the quality of the seeds.

MATERIAL AND METHODS

Immediately after arriving at the research laboratory, broccoli seeds (*Brassica oleracea* var. *italica* from Ramoso de Brasília cultivar) were submitted to the following tests: germination (93.71%), physical purity (99.56%), mass of 1000 seeds (4.2×10^{-3} kg; and cv = 2.37%) and moisture content (6.02%). During experiments, seeds were conditioned in a refrigerator at 4°C, in closed plastic containers, to avoid moisture exchanges with the environment.

Experimental Setup

Seeds coating was made in a conical-cylindrical spouted bed (Figure 1). About 1000 g of seeds were loaded to the vessel (Almeida & Rocha, 2002). A typical run started with the injection of air into the bed filled with seeds. The spouting air was heated to a specific temperature. Air flow rate was controlled to keep the spouting stable. The coating suspension was pumped at constant flow rate to the double-fluid nozzle. The suspension was atomized and sprayed over the seeds in the bed. Runs 1 to 4, 5 to 8 and 9 to 12 took 90, 105 and 120 minutes, respectively. The coating time was related to the stability of the seeds movement in the bed and varied with suspension flow rate.

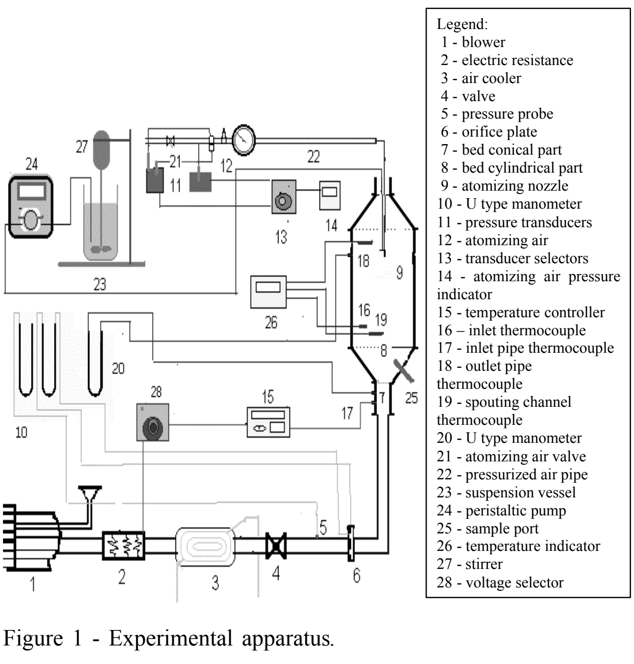

Figure 1 - Experimental apparatus.

Coating suspension

The coating suspension was made up of hydroxy-ethyl-cellulose (HEC) plus inert material, which provided a uniform, water-soluble coating surface, without favoring moisture absorption from air, as defined in preliminary tests and also based in earlier research works by Queiroz Filho (1997). The suspension scattering on the seed surface and adequate atomization was also considered to define the coating suspension formulation. Table 1 lists the suspension components and quantities. The suspension was sprayed inside the bed, immediately above the seeds, through a double fluid nozzle. The suspension solids concentration was 11%.

Experimental design

A 2 × 3 factorial design with four central points was used to investigate the effect of the independent variables: coating suspension flow rate (Ws), spouting air temperature (Ta), and atomizing air pressure (Pa), on the seed germination and vigor, assessed by the tests of accelerated aging, and springing in soil. Table 2 shows factors and respective levels used in the experimental design. As it was not possible to repeat all trial, four replications were made at the central point to analyze the reproducibility and to estimate experimental error, enabling the adequate statistical analysis.

A completely randomized trial was used to assess possible differences in germination, accelerated aging and speed of germination in soil of coated and non-coated seeds. The trial considered 13 treatments with four replications. The treatments encompassed 12 coating assays

Table 1 - Suspension composition.

Component	Mass weight %
Hidroxy-ethyl-cellulose	3.50
PEG 6000	0.75
Magnesium stearate	1.00
Titanium dioxide	2.25
Talcum	3.50
Water	89.00

Table 2 - Independent variables and levels of the experimental design.

Factor	Levels		
	-1	0	1
Ta (°C)	50	60	70
Ws (kg s^{-1}).10^4	1.014	1.184	1.353
Pa (Pa).10^{-5}	1.034	1.379	1.724

including the non-coated seeds. All statistical analysis were carried out using the software Statistica for Windows (2000). Comparisons of means were made by the Tukey test (α = 0.05).

Moisture content

The moisture contents were determined before tests of germination and vigor, by the oven method at 105 ± 3°C, for 24 hours, using three samples of each group, according to the Regras para Análise de Sementes (Brasil, 1992). Results were reported in wet basis.

Germination

The broccoli seeds germination was assessed for each 200-seeds random sample, both coated and non-coated. Fifty seeds were sowed per germination plate (gerbox) (n = 4), containing absorvent paper moistness with distilled water at about 2.5 times paper mass. Seeds were uniformly spaced to avoid contamination and competition. Gerbox plates were closed and placed in a germinating chamber set at 25 to 30°C, with continuous lighting. Assessment of seedlings was made according to Regras para Análise de Sementes (Brasil, 1992).

Accelerated aging

The accelerated aging test was made with 50 seeds, four replications. Seeds were spread on a bottom-screened aluminum tray, attached to a gerbox type plastic box, serving as mini chamber. Forty milliliters of water were then added to the gerbox plate, which was taken to a chamber, according to the method proposed by the Association of Official Seed Analysis (1983). Seeds remained in the chamber at 42°C, for 24 hours. Seeds were then allowed to germinate, following methodology described for the germination analysis, but with only one counting, which was made five days after sowing.

Seed germination speed

The assay on seeds germination speed in soil involved 100 seeds in each plot with four replications, 25 seeds each. Seeds were sowed in 0.3 m long, 0.01 m deep-groves spaced 0.05 m. The soil was constantly irrigated during the test. Daily observations were made; after the first day one seedling was springed from the soil. Amount of seedlings above 1.5 cm was recorded daily until there was no more seedling springing. The speed of seeds germination was calculated according to Edmond & Drapala (1958), mentioned by Vieira & Carvalho (1994), where:

$$VE = \frac{(N_1E_1) + (N_2E_2) + ...(N_nE_n)}{E_1 + E_2 + ... + E_n}$$

"VE" is speed of seeds germination, "E1, E2, ..., En", number of springing seedlings in each day and "N1, N2, ..., Nn", number of days from sowing at each counting day.

Microscope analysis

About 0.01 kg was arbitrarily sampled at the end of each coating assay and 20 seeds were selected for analysis. The seeds' coating quality, uniformity and homogeneity, presence of cracks and splits on the seed surface were observed under microscope (Stereozoom microscope; 40 x magnification).

RESULTS AND DISCUSSION

There were no differences on germination, accelerated aging and speed of seed germination in soil, between coated and non-coated seeds (Tukey test; α = 0.5%) (Table 3). The Pareto diagram (Figure 2) represents the coated seeds germination. The absolute value of the standard effect of 3.17 refers to the confidence limit range of 0.05. All effect values below this level, identified by the dashed vertical line, are not significant.

The atomizing pressure exerted negative effect over coated seeds germination. On the other hand, the air temperature did not have effect, actually being the least significant parameter. The negative response for germination values obtained when pressure was increased, may result from mechanical shock. When the atomizing pressure was increased from 15 psig to 25 psig, increasing impact of the seeds on the bed wall was observed.

The increasing mechanical shocks between the seeds and the vessel wall, observed for high atomizing pressure, resulted from the small bed dimensions and nozzle position. The bed dimension, on the other hand,

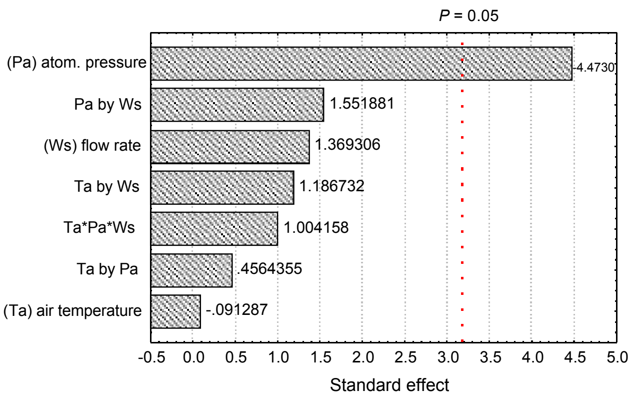

Figure 2 - Pareto diagram for coated seeds germination.

Table 3 - Operating conditions and results.

Assay	Temperature	Pressure	Flow rate	Germination	Aging	Germination in soil	Moisture content
	Ta	Pa	Ws				
	°C	(Pa).10^{-5}	(kg s^{-1}).10^{4}	---------- %	----------	days	(%) wb
1	50	1.034	1.014	97.0	68.5	4.35	8.0
2	70	1.034	1.014	96.0	70.5	4.55	6.2
3	50	1.724	1.014	89.5	66.5	4.39	8.0
4	70	1.724	1.014	87.0	72.7	4.47	6.3
5	50	1.034	1.353	96.5	63.0	4.48	10.4
6	70	1.034	1.353	96.0	67.5	4.42	6.4
7	50	1.724	1.353	90.5	61.0	4.37	11.7
8	70	1.724	1.353	94.0	73.2	4.52	8.0
9	60	1.379	1.184	89.5	68.0	4.27	8.0
10	60	1.379	1.184	91.0	66.5	4.36	8.0
11	60	1.379	1.184	90.5	73.0	4.52	7.2
12	60	1.379	1.184	94.0	65.0	4.35	8.0
Mean rate				92.8	68.4	4.40	
Non-coated				95.5	73.7	4.37	7.2

was a function of the maximum load of seeds specified per assay. The nozzle position was defined in preliminary tests in the aim to attain the maximum area of exposure of seeds to the coating suspension.

Seeds germination was not affected by changing flow rate of the coating suspension. However, a negative effect was observed when suspension flow rate of was 6 mL min^{-1} and pressure was 25 psig, which resulted in the changes in the bed dynamics. Seeds with greater suspension thickness on their surface became heavier and, as a consequence, reached the bed wall at a lower speed. Smaller impact between the seeds and the vessel wall was observed during the coating process, resulting the negative effect of the interaction of a low suspension flow rate and a high pressure of atomization.

The small influence of the air temperature may be explained by the fact that heated spouting air was kept at a constant temperature at the bed inlet. When in contact with the seeds, humidity increased by the water mass transfer during the suspension drying on the particles and equilibrium was reached between the spouting air temperature, the suspension temperature and the seeds temperature. With continuous spraying during the coating process, the seeds were always involved with a thin humid film, and so their temperature equaled the wet bulb temperature of the air, what is much lower than the entering air temperature. During each run, the temperature was measured in four places within the bed and a low temperature of the bed of particles was confirmed. For instance, for test six, the incoming air temperature was 70°C, the out-coming air temperature was 30°C, the spouting jet temperature was 35°C, and the annulus bulk

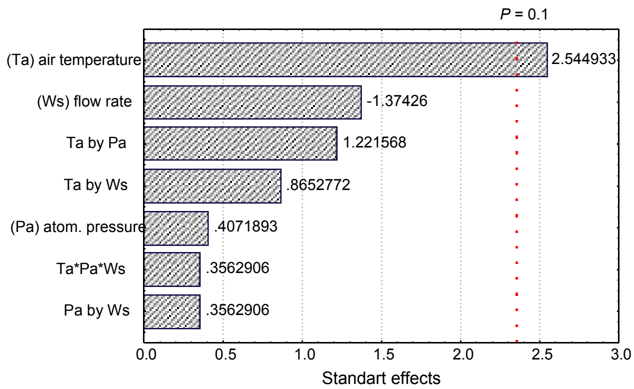

Figure 3 - Pareto diagram for coated seeds accelerated aging.

temperature was 32°C. Temperatures between 25 and 35°C, do not affect percentage of seeds germination of *Brassica napus* L. fluidized for 40 min (Drew, 1989). However, seeds fluidized at temperatures of 40°C, for over 40 min, had increasing abnormal seedlings. The results obtained by Drew (1989) were analyzed for an adequate choice of a safe temperature range to coat *Brassica oleracea* L. in this work.

The coated seeds germination presented values between 87 and 97%. The coating process did not affect seeds germination at the applied operating conditions. Therefore, the essential embryo structures were not damaged. This analysis is coherent with Mello et al. (1999), who studied the physiologic quality of the broccoli seeds (*Brassica oleracea* L. var. *italica plenk*).

Figure 3 refers to the statistical analysis of the independent variables on the accelerated aging of the coated seeds. The absolute standard effect of 2.35 is the limit for the effect significance at a confidence level of 90%. The accelerated aging of the seeds was positively affected by the spouting air temperature; the suspension flow rate had negative but not significant influence. Nevertheless, an interaction between these two variables was observed in the assays five and seven. In this case, the temperature value was 50°C and the suspension flow rate was 8 mL min^{-1}. Seeds reached moisture contents of 10.4 and 11.7% and accelerated aging of 63 and 61%, respectively. Probably, higher moisture contents lead to higher stresses in the accelerated aging chamber. Care must be taken to assure uniform moisture content among the seeds, a requirement for this test (Loeffer et al., 1988).

The seeds accelerated aging ranged from 61 to 73%, there were no difference among the treatments (Table 3). The coating process did not affect the physiologic quality of the seeds. The residence time in the accelerated aging chamber and the results obtained in this work are different from the ones reported by Mello et al. (1999), who used a different broccoli cultivar.

The coating process did not alter the speed of seeds germination in the soil. Both coated and non-coated seeds germinated within four to five days. As field conditions vary, results can not be compared to others obtained at different seasons or places. Tower & Maguire (1990) observed that, even running seeds‘ speed germination test in a recommended time, changes in temperature along the test delayed the germination.

Figure 4 - Microscope view (40x) of non-coated broccoli seeds (a) and broccoli seeds coated in spouted bed (b).

Quality of seeds surface coated in spouted bed

The broccoli seeds presented a testa made up of cells of mucilaginous material, which added resistance and strength to it. Figure 4(a) shows non-coated seeds, which were analyzed by optical microscope. The surface layer is homogeneous, smooth and shining. Figure 4(b) shows broccoli seeds coated in spouted bed, run 2. In this test, the relative growth of the seed mass was 6.95%. Similar results were obtained in the other runs. During the spouted bed runs, the sprayed suspension spread well and uniformly throughout the surface, as confirmed by optical microscopy. The analysis revealed homogeneous, uniform and smooth coating. Seeds kept the superficial layer characteristics, not suffering losses, fissures, cracks or bruises.

CONCLUSIONS

The spouting air temperature up to 70°C does not affect the seeds germination when the suspension coating is continuously applied. It is possible to coat broccoli seeds in a spouted bed, using the operating conditions here in described, up to 120 minutes, without altering the germination and the vigor of the seeds and the physical quality of the testa.

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