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Optimization of Zeolite Beads Drying for Vegetable Seeds

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ABSTRACT

Drying seeds and maintaining low seed moisture content is critical in hot and humid climatic conditions. In this study Zeolite beads which are inert adsorbent materials have been used for drying tomato and onion seeds. Response Surface Methodology was employed to optimize the parameters of drying in central composite experimental design. The seeds of tomato cv. *Pusa Ruby* and onion cv. *Nasik Dark Red* with initial moisture content of 8.6 to 15.4% dry weight basis (d.b.), were dried at five levels of residence time (1.3, 4, 8, 12, 14.7 h) and five levels of seed bead ratio (1:0.33, 1:0.5, 1:0.75, 1:1, 1:1.17). Second degree polynomial models were found significant for each response viz. germinability, vigour and final moisture content. The optimum values of process variables was found to be 1:0.5, 10.8 hours and 11.84 %, seed bead ratio, residence time and initial moisture content, respectively in case of tomato seed. Seed bead ratio, residence time and initial moisture content of 1:0.62, 6.52 and 13.62, respectively were found optimum for onion seed

Introduction

India is next only to China in vegetable production with an annual production of 162.2 million tons from 9.2 million hectares having a share of 14 per cent to the world production (Anonymous, 2015). Vegetables play a major role for nutritional and economic security, especially in Indian context, where major part of population is vegetarian. Our demand of vegetables will be 225 million tons by 2020 and 350 million tons by 2030 (Anonymous, 2011). Among all cultivated vegetables; onion and tomato are important vegetables as they are the most vital ingredients in Indian food, and shortages can cause price increases and social unrest. The major challenge is therefore to make quality seed available at the time of sowing. It has been observed in multi-location coordinated trials under National Seed Project that about 20-30 % average increase in productivity could be achieved with the use of quality seed (Chowdhary, 2004). Seed being a living entity, its moisture content is a critical factor which influences its longevity, since water serves as a fluid medium and stabilizes the structures of macromolecules. The moisture in the seed is an important substrate in many reactions and its effect on phospholipid structure plays an important role in membrane permeability (Leopold and Vertucci, 1989). The moisture content is frequently higher (ranging 15-18%) at the time of harvest than the optimum required to obtain the best potential life of seed. It is widely accepted that drying of seed prior to storage, increases their longevity and germination capabilities. Reducing seed moisture to low level (around 5%) increases storability of some seeds even under ambient conditions (Zheng, 1998). The effect of moisture content on seed performance is more predominant under hot and humid climatic conditions.

Various methods of seed drying have been adopted ranging from traditional; sun drying to sophisticated drying systems like the microchip controlled system. Most of these methods use air as drying media and its temperature as driving factor for rate of drying. The higher temperatures used for drying makes the process faster but are often a threat to seed quality. The quality of high value low volume seed is very sensitive tohigh drying temperatures (Javaregowda *et al.*, 1990). Sun drying is time and labour intensive and is also weather dependent. It also affect seed quality traits adversely (Rao *et. al*, 2006). The important factors affecting the drying process are initial seed moisture content, drying air temperature, relative humidity and air velocity (Amer *et al.*, 2003). Among high value, low volume seeds, the tomato and onion seeds are critical and sensitive to high temperature drying, which induces drastic ‘heat injury’. This heat injury reduces germination, vigour and shelf life of seeds considerably. Alternatively desiccant drying is one option. Silica gel, Betonite and some salts like calcium sulphate, calcium chloride, sodium chloride have been used for drying of seed. It has been found effective in reducing moisture content of seed (Xiorong *et al*,. 1998; Zheng *et al.*, 2001; Hu *et al.*, 2002; Zeng *et al.*, 2006). Normally desiccant drying is very slow process. Also though some desiccants like silica gel can be regenerated by heating, there is loss of water holding capacity of silica gel due to polymerization after repeated heating. These methods therefore make a non-viable option.

Recently, Zeolite beads have been developed which can be used as drying desiccant (Asbrouck and Taridno, 2009). Zeolite beads have a higher affinity for water than silica gel even at low humidity levels. Also, there is no loss of water holding capacity of drying beads after repeated regeneration process. This is in contrast to silica gel, which loses effectiveness with repeated regeneration. The Zeolite beads have an extremely high capacity to adsorb water, even at very low air humidity, making them optimal drying material. The adsorption process is fully reversible and of purely physical nature. The beads can be regenerated indefinitely by heating to elevated temperature. Drying beads are modified ceramic materials (aluminum silicates and zeolite) that specifically absorb water molecules and hold them very tightly in their

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microscopic pores. These beads are available in 5 mm and 8 mm sizes. These beads are non-toxic and essentially inert, like ceramics.

Materials and Methods

The popular variety of tomato and onion seeds, cv. *Pusa Ruby* and *Nasik Dark Red*, respectively were procured from the local market. The initial moisture content of tomato and onion seeds were 8.7% and 11.2% (db), respectively. The samples were cleaned and graded using pneumatic separator and air screen machine.

Moisture conditioning

The samples were either dried or sprinkled with predetermined quantity of water to bring the moisture levels in the range of 9 to 15.5% (db) as per requirement of design of experiment (9, 10, 12, 14 and 15.5 %). The water sprinkled samples were thoroughly mixed by hand, packed in airtight polythene bags and kept for 48 h under refrigerated condition (at about 15°C) for moisture equilibration. The bag was shaken at regular intervals for uniform distribution of moisture inside the sample. Samples were kept in a tray dryer at 40 °C until the desired lower moisture content was attained. Moisture content was determined using standard hot air oven method (ISTA, 1993).

Seed Quality Analysis

The seed quality *i.e.* germination and vigour evaluation of samples was carried out. Fifty hundred seeds in three replication were subjected for germination test in top paper method (ISTA 1993). The samples were kept in the germinator for 14 days at temperature of 20°C. The number of normal and abnormal seedlings and dead seeds were recorded. The germination % was expressed on the basis of normal seedlings. Vigour index was calculated by multiplying standard germination percentage by seedling dry weight in mg (Abdul-Baki and Anderson, 1973). Ten normal seedlings of each replication were drawn at random and were subjected to reckon vigour index (VI). The seedlings were dried at 104 °C in oven for 8 h to get seedling dry weight. The vigour index was obtained by multiplying germination % with seedling dry weight.

Design of experiment

The central composite rotatable design (CCRD) experiment with three independent variables *viz.* initial moisture content (IMC), seed bead ratio (SBR) and residence time (RT) were employed for optimization. Original values of each variable was codded for five levels as -1.682, -1, 0, +1 and +1.682. Three important seed quality parameters *viz.* final moisture content (FMC), germination percentage (GP) and vigour index (VI) were considered as dependent parameters. Response surface regression was performed for analyzing the spectral properties of the fit surface and calculating the ridge of optimum response. In the following case, three mathematical functions of *f* areas summed to exist for *Y*:

Y = *f* (seed bead ratio, residence time and initial moisture content)

A second-degree polynomial equation in the following form can be used to approximate the function fk.

$$Y = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{2} \sum_{j=i+1}^{3} \beta_{ij} X_i X_j + \sum_{i=1}^{3} \beta_{ii} X_i^2$$

where, β_0, β_{ii}, β_{ij} are regression coefficients and *Xi*'s are the coded independent variables of seed bead ratio, residence time and initial moisture content while *Yk* is the dependent variable or the measured response.

Equations were derived by response surface regression using seed bead ratio, residence time and initial moisture content as independent variables while the final moisture content (FMC), germination percentage (GP) and seed vigour index (VI) were considered as responses. Using response surface methodology (RSM), an optimum combination of seed bead ratio, residence time and initial moisture content was determined.

Drying experiments were carried out in air tight containers, mixing seed with beads at room temperature for specified resident times. Seed and beads were mixed in the specific ratio (1:0.33, 1:0.5, 1:0.75, 1:1, 1:1.17) as per experimental design. The resident time were 1.3, 4, 8, 12, 14.7 h as per experimental design. The seed and bead were separated using sieve. Final moisture content of separated seed was determined using standard hot oven method.

Numerical optimization

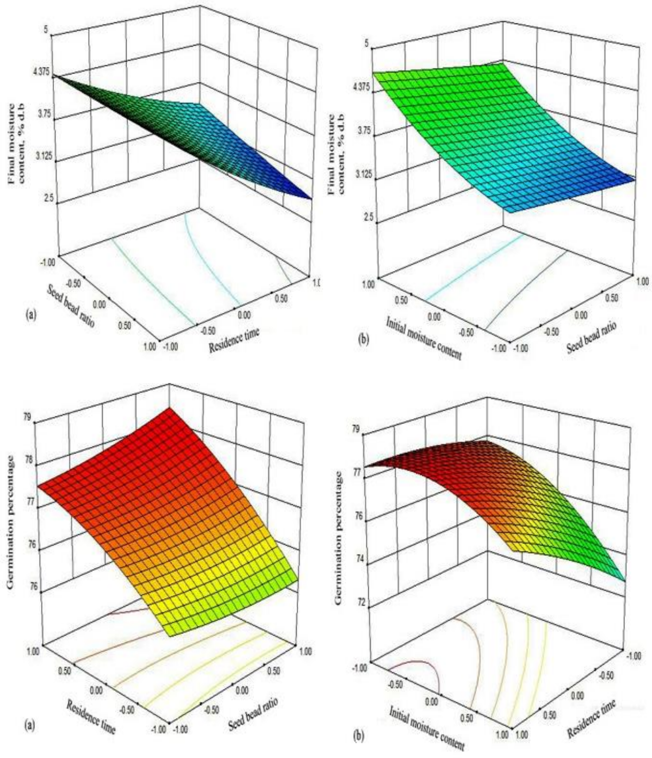
The optimum level of the selected variables was obtained by solving the regression equation using a multi-stage Monte-Carlo optimization (Conley, 1984) program and also by analysing the response-surface plots (Khuri and Cornell, 1987). Numerical optimization for the process parameters led to the preparation of a drying protocol for obtaining the best results. Desired goals were assigned for all the parameters for obtaining the numerical optimization values for the responses. All the processing parameters were minimized except initial moisture content. Final moisture was minimized while germination percentage, and vigour index were maximized. Design Expert 8.0.7.1 software was used for numerical optimization.

Result and Discussion

The study demonstrated that the tomato and onion seeds could be dried to 2.8 % and 3.6 % from 8 – 16 % moisture content with beads at room temperature efficiently. Seed bead ratio, residence time and initial moisture content had found significant effect on drying extent (final moisture content) for both the seed. It was observed that the seed bead ratio and residence time had a negative correlation with final moisture content (Fig.1 and 2). Seed bead ratio expressively affected the drying rate as well as drying extent. The lower final moisture content with increase in seed bead ratio may be attributed to the higher surface area available for moisture adsorption in beads drying. It all described the capability of beads drying to ultra-drying level. The ultra-drying is a proven aid for enhancing longevity of seed (Zheng *et al.*, 2001 and Pandita *et al.*, 2003). The residence time and initial moisture content articulated significant effect on important seed quality trait *i.e.* germination percentage ($p < 0.01$) for seeds under the study. However, seed bead ratio was found insignificant with respect to germination percentage of both the seeds. The dried tomato and onion seed expressed germination percentage in the range of 71 to 78% and 68 – 74 %; respectively. Moisture content below 4%, expressed significant reduction in seed quality attributes. It may be due to desiccation of structural water from seed which has also been reported by Ellis and Roberts, 1980. The level of germination of both the seeds were found ominously higher than IMCS (Indian Minimum Seed Certification Standards) of respective crop seeds dried up to more than 4% moisture content. Unlike, hot air drying system, there was no least adverse effect of drying on seed quality. Hot air drying induces hydrolysis of starch in the embryonic axis and in turn affects seed germination significantly (Seyedin *et al.*, 1984).

The dried tomato and onion seeds demonstrated significantly high vigour. This clearly indicated that there was no any adverse effect on seed quality of bead drying. However, Siddique and Wright (2003) reported that hot air drying induced injury to seed by enzyme inactivation and causing rapid loss of viability. It signifies superiority of beads drying over hot air drying. Positive correlation was demonstrated by residence time with vigour. However, initial moisture content illustrated negative correlations. Residence time was found to be negatively correlated with vigour (p 0.05). It was also strengthened by surface plots (Fig. 1 & 2).

The best fitted second degree polynomial regression model obtained after removing non-significant terms for prediction of germination percentage, vigour and final moisture content using SBR, RT and IMC for tomato and onion seeds are presented in table1. High value of R^2 clearly indicated adequacy of the model. Negative coefficient of initial moisture content in germination and vigour models indicated that germination and vigour reduces with increase in values of the initial moisture content. However, presence of negative quadratic term in germination percentage and vigour models of initial moisture content revealed that linearity of change in germination & vigour was limited to limited range of initial moisture content, beyond which there was decrease in germination percentage and vigour more rapidly. However, presence of positive quadratic term of initial moisture content was found in FMC model; which indicated that final moisture content linearity was progressed to limited range after it there was rapid increase of final moisture content. Linear positive coefficient was observed with residence time for germination and vigour. However, seed bead ratio was not found significant for affecting seed quality parameters of tomato and onion seeds. It implied that the beads were not affecting the quality of seed during the drying period



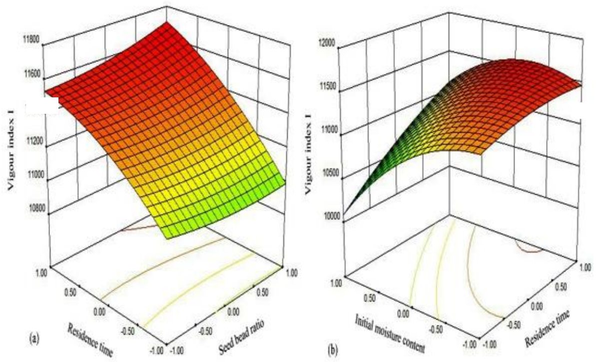


Fig. 1. Effect of seed bead ratio, residence time and initial moisture content on germination percentage, vigour indices and final moisture content for tomato seed.

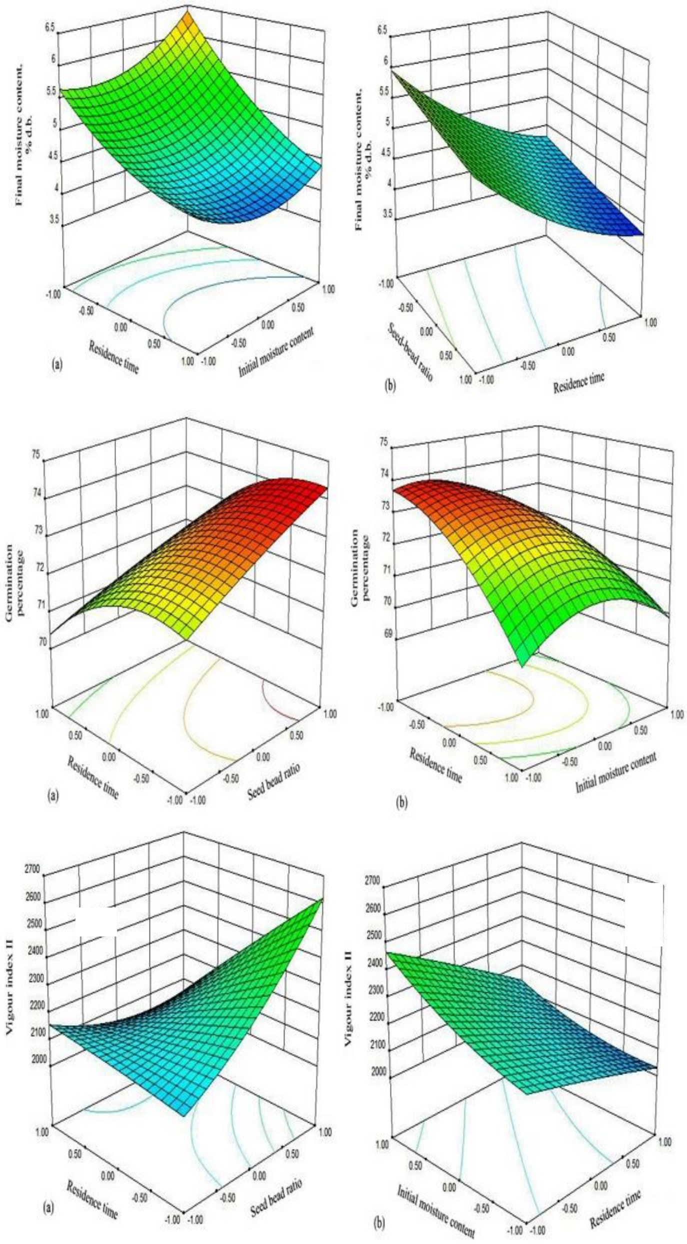


Fig 2. Effect of seed bead ratio, residence time and initial moisture content on germination percentage, vigour indices and final moisture content for onion seed

Table 1. Model equations for germinabilty, vigour and final moisture content for tomato and onion seed.

Model Equation	R^2	CV
$FMC_t = 3.68 - 0.15\,SBR - 0.65\,RT + 0.63\,IMC + 0.18\,IMC^2$	96.59	5.38
$FMC_o = 4.59 - 0.27\,SBR - 0.80RT + 0.18\,IMC - 0.26\,RT^2 + 0.37\,IMC^2$	94.25	5.65
$GP_t = 77.17 + 1.10\,RT - 1.45\,IMC - 0.96\,IMC^2$	84.42	1.43
$GP_o = 73.02 + 0.83\,SBR + 1.12\,RT - 0.79\,IMC - 0.81\,IMC^2$	87.55	1.36
$VI_t = 11372.02 + 298.75\,RT - 391.07\,IMC - 297.19\,IMC^2$	84.98	2.69
$VI_o = 1877.58 + 43.5\,RT - 53.16\,IMC - 35.9\,IMC^2$	81.22	2.59

The overall optimum values obtained for seed bead ratio, residence time and initial moisture content in case of tomato seeds were 1:0.5, 10.8 hours and 11.84 percent, respectively. The corresponding values for responses i.e. final moisture content and germination percentage in case of tomato were 3.94 % and 76.99 % with high vigour, respectively. On the other hand, the optimum values for seed bead ratio, residence time and initial moisture content were 1:0.62, 6.52 and 13.62, respectively for onion seed. The corresponding values for onion seed were found to be 5.55 % and 71.08 with high seed vigour.

Summary

Zeolite beads were found efficient in drying of tomato and onion seeds up to ultra-dry level. The dried seed exhibited higher germination percentage than Indian Minimum Seed Certification Standards (IMSCS) for both the seed. Unlike, hot air drying system, there was least adverse effect of drying on seed quality. The developed models were found significant. It was originated that the residence time significantly affected the seed vigour indices for tomato. However, the effect on seed vigour indices were not significant in onion seed. Tomato seed could be dried from 11.84 % moisture content to 3.94 % moisture content in 10.8 h with seed bead ratio 1: 0.5, which maintained germination percentage 76.99 % with high vigour. However, in case of onion seed drying with beads optimum required seed bead ratio and residence time were 1:0.62 and 6.52 h, respectively. It could dry onion seed from 13.62% to 5.55% with 71.08 % germination percentage. The optimum process variables were different for the tomato and onion seed, which illustrated that they had structural, physical or genetical differences that affected these traits and regulated seed quality.

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