Microwave Drying of Seeds of Agricultural Interest for Ecuador

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Seed conservation in Ecuador

Agriculture is a predominant activity in Ecuador, especially in the province of Cotopaxi, where this sector is one of the principal economic activities. The main crops grown in Cotopaxi are sweet maize (chulpi), soft maize (choclo), corn, cocoa, sugar cane, potatoes, barley, bananas including plantain which is one of its variety, and dried beans[1]. For most of these crops, seed conservation is an important issue within agricultural practices that requires a drying process for maintaining seed viability during storage. Moreover, seed conservation in Ecuador is not only important from an agricultural point of view, but also as a strategy for the conservation of the country's wild plant biodiversity.

The main method of drying seeds in Ecuador is by exposing them to natural air and the sun (see Figure 1). This method is widely employed because this form of energy is free and abundant in all parts of the world, especially in tropical countries. Moreover, it does not require expertise. However, it has several disadvantages since it is extremely weather dependent, it involves very long drying times, and it requires large spaces for drying. In addition, the total control of the drying process is not possible, and a non-uniform drying of the products may be the result. Besides, the seeds are exposed to climatic variations, which diminishes their viability and quality. They are also susceptible to threats such as environmental pollution, pests, diseases, and contamination with soil and dust.

Since agricultural activity and biodiversity conservation are priorities for the Ecuadorian State[2], research into new technologies to improve the drying process would be of great interest. Accordingly, the main objective of this study is to assess the feasibility of applying microwave drying to seed conservation for its potential use in Ecuador.

Figure 1. Solar drying of quinoa seeds in Latacunga, province of Cotopaxi, Ecuador.

Microwave drying of seeds

The microwave drying of seeds has attracted considerable attention in the literature over the past decade. However, only a few works have focused on the drying of seeds for conservation purposes. The aim of most of these studies has been to assess the quality of the seeds, mainly, through four parameters: germination rates, seedling vigour, physico-chemical properties and pest control. An increase in the germination rate (G.r) of the species analyzed depends on the power density (P.d), expressed in Watt/gram, and the microwave drying procedure employed, as can be seen in Table 1.

Table 1. Germination rate by species and the power density employed (best results obtained to date)

Scientific name (common name)	P.d. [W/g]	G.r. [%]	Ref.
Cicer arietinum L. (bengal gram)	6	100	[3]
Glycine max (L) Merr. (soybean)	0.13	95	[4]
Triticum aestivum L. (wheat)	0.3	96	[5]
Vigna radiata (L.) R. Wilczek (Green gram)	6	80	[3]
Zea mays L. (corn)	2.8	97	[6]

In some cases, such as rapeseed, no germination occurs over the power ranges studied[7]. However, in some species, such as green gram, moth bean, and Bengal gram, it has been proven that the best germination rates are achieved using a low power density and a shorter exposure time[3]. A wide range of physico-chemical properties has been analyzed after microwave drying. The most common properties considered have been the bulk density of the seeds, stress cracking, and the percentage of chemical elements (amino acids, nucleic acids, magnesium, phenolic compounds, etc.). It has been found that physical properties are affected by microwave assisted drying. The results indicate that an increase in drying rate at higher power levels reduces the bulk density of corn[6, 8-10]. Besides, in rapeseed[7] more than 60% of broken seeds were observed in the range 400-800 W.

Microwave irradiation has also been used to reduce the contagion by different insects with promising results. Reddy et al.[11] found that the percentage of wheat seeds infected by Fusarium graminearum could be reduced to below 7% (from 36% for the controls), while retaining a seed germination level as high as 85%. Similar results were obtained by Warchalewski et al.[12] with a significant level of insect pest elimination, with exposure times of up to 90 seconds and grain temperatures not exceeding 64°C. Moreover, Pande et al.[13] achieved a 99.5% insect mortality rate, in green gram seeds, without reducing quality parameters such as the green color of seeds at high power levels (808 W for 80 seconds). However, no germination tests were performed to evaluate the effect of high power energy on seed viability.

The studies analyzed employ a wide range of methods. For example, different amounts of seeds, a broad range of power levels, and different physico-chemical parameters to assess quality criteria have all been used in these seed studies. For these reasons, it is difficult to draw general conclusions. The common pattern in the cases studied, was for microwave assisted drying to greatly reduce the drying time compared to other techniques[4, 6, 14]. In general, with microwave techniques, the drying rate increases as the microwave power and temperature increase[15-18]. In addition, it is generally agreed that energy efficiency is enhanced when microwave technology is applied for drying purposes. However, the number of studies that examine this aspect in seeds is limited[19, 20- 24].

For the reasons mentioned above, microwave drying is highly recommended for drying seeds because essentially it reduces the drying time and energy consumption. However, in the case of biological materials it is necessary that the quality parameters of the final dried product be carefully analyzed. Therefore, to establish the feasibility of microwave technology for the drying process, various parameters such as drying time, energy efficiency and quality, must be considered simultaneously. Most of the studies are based on drying rate and quality criteria, with energy consumption being evaluated only in a few studies[16,19,25].

In most cases, tests have revealed that microwave drying increases the drying rate without impairing the quality of the final product. Nonetheless, the methodology employed, and the power level need to be carefully chosen in order to avoid damage to the samples, (e.g. the germination rate and the quality of the final product decrease at higher power levels or under overexposure to microwave radiation)[6,12,26]. It should also be pointed out that the time required for drying the seeds depends not only on the power or temperature employed but also on the initial moisture content[6]. A higher initial moisture content requires a longer exposure time, which is a matter for concern, especially in relation to tropical or subtropical species. One of the problems that may cause a significant decrease in the germination level is the presence of hot spots during the drying process. This subject has been discussed by Manickavasagan et al.[27, 28] where they observed that temperature peaks above 65°C prevent the process of germination from taking place.

Most of the studies analyzed have been performed in order to investigate the effects of different microwave power levels on the quality parameters mentioned above. Fixed microwave power levels have been applied during the entire process, but no temperature control has been included in the studies. The absence of a temperature control causes the presence of hot spots. Moreover, during the drying process, the mass of the product decreases, due to the loss of the initial moisture and, therefore, the power density increases during the last part of the drying stage, leading to high temperatures, which cause charring of the sample and, consequently, a decrease in seed viability and a deterioration of the quality of the final product. According to Li et al.[29], to achieve the ideal drying effect over the entire microwave drying process, the sample temperature must be controlled and the microwave power must be adjusted accordingly, especially in the final stage of the drying process.

Temperature control during the microwave drying process has been performed only in a few studies[29, 30, 31, 32]. However, in these cases the drying effects in terms of time, energy efficiency and product quality were improved. The sample temperature in microwave drying is more difficult to control than in hot-air drying, where the product temperature never rises above the air temperature. Therefore, the best method of temperature control is to adjust the power taking into account the power–moisture content relationship and feedback temperature control[32]. Furthermore, adequate temperature and power adjustment will avoid the need to use combined techniques, which are more complex and expensive to implement.

Our contribution to microwave seed drying

Quinoa and amaranth, crops indigenous to the Andean region, have acquired great importance worldwide due to their nutritional properties and their potential to adapt to different agroclimatic conditions. Owing to the morphological characteristics of quinoa seed, the drying of this material is very susceptible to climatic variations, especially to any increase in environmental humidity, which can cause the seed to germinate during the air-drying process. Moreover, the tiny size of amaranth seeds also makes them very susceptible to climatic variations. For example, they can easily be dispersed by the wind with the consequent loss of product. In short, an improvement of the drying process based on techniques that allow a better control and make it more energy efficient is necessary.

Previous studies on corn seed drying[6] have shown that the use of microwave technology reduces the drying time and energy consumption without affecting the viability of the seeds. However, hardly any data are available on the quality of the seeds. Furthermore, in respect of quinoa and amaranth, there are no data at all relating to the use of this technology in the drying process.

In the project titled "Evaluation of the microwave drying process of seeds of agricultural interest for the Cotopaxi Province", which is being currently developed by our research group[33], the drying process of quinoa and amaranth seeds in a microwave oven and in a conventional electric dryer at three different temperatures is being evaluated. The drying curves of the seeds studied will be obtained for the three temperatures in two types of furnaces. This will allow us to determine the drying time required for each technology and temperature in order to attain the optimal conditions of humidity for the conservation of the seeds. Moreover, the energy consumption will be measured in order to evaluate the energy efficiency of each of the experiments.

To assess the quality of the dried seeds achieved by the different technologies employed, four parameters will be evaluated: grain surface deterioration or contamination, germination rates, seedling vigour and physico-chemical properties. A comparison of the results obtained, together with the energy efficiency data, will make it possible to determine whether the use of microwave technology, at controlled temperature, reduces the drying time and energy consumption without impairing the viability and quality of the seeds. If the results expected of this project are achieved, they will contribute to the development of an efficient and competitive technology for the drying of seeds of agricultural interest for implementation on a commercial scale in the province of Cotopaxi.

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For further reading:

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