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Effect of thermal treatments on vitality and physical characteristics of bean, chickpea and lentil

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ABSTRACT

Thermal disinfestation treatments are relatively easy to apply, leave no chemical residues and may have some fungicidal activity. However, temperature and time combinations required to kill insect pests may meet or exceed those that reduce the viability of seeds, nutrients content, shelf life or technological characteristics. The aim of this study was to investigate the effect of thermal treatments (different temperature and time combinations) on physical and biological characteristics of bean, chickpea and lentil. Seed samples of common bean, chickpea and lentil were treated at low (12, 24 or 48 h at −18 °C) or high (30, 60 or 90 min at 60 °C) temperature. Seed germination, mean germination time, physical characteristics: solids loss, electrolytes leached and firmness after cooking, were determined. The use of thermal treatments for disinfesting seeds of bean, chickpea and lentil represent a physical technique of pest control that can be harmless for seeds destined for crop production (especially for organic farming) or to be stored in germplasm banks. Moreover, thermal treatments can be applied also to grain legumes used as food by humans, with no significant effect on lentils and with a reduction of cooking time for chickpeas. Beans should be treated only with cold treatments and for no more than 24 h.

1. Introduction

Legumes, along with cereals, have been widely used by humans since early times and play an important role in the traditional diets of many regions throughout the world. Early farmers highly appreciated legumes for their nutritive value and long-term storability. Among the plant species, legume seeds contain a moderately high amount of dietary proteins thus providing the major vegetal source of these nutrients. Their use as food is still limited as protein quality in grain legumes does not reach the same level as in animal products due to the unbalanced amino acid composition (low amounts of sulphur-containing amino acids), the low protein digestibility and the presence of several anti-nutritional factors (Barampama and Simard, 1994; Bressani and Elias, 1980; Norton et al., 1985). Legumes have a high caloric content and are a good source of carbohydrates, dietary fibre, vitamins (especially B-group) and minerals such as K, Zn, Ca and Mg (Meiners et al., 1976; Reyes-Moreno and Paredes-Lopez, 1993). They also contain a variety of micronutrients and phytochemicals that can play an important role in human metabolism. Legumes are usually cooked before being used in the human diet. This improves the protein quality by destruction or inactivation of the heat labile anti-nutritional factors (Chau et al., 1997; Wang et al., 1997; Vijayakumari et al., 1998) but causes considerable losses in soluble solids, especially vitamins and minerals (Barampama and Simard, 1995).

The increase of prosperity in Western countries resulted in an increase in the consumption of meat and other sources of proteins, reducing the use of legumes and their dietary role. Long cooking time is another factor responsible for wider under-utilization of legume seeds. This characteristic is mainly due to genetic and structural factors but may also be determined by seed age and storage conditions.

Another major problem for production and storage of legumes is infestation by insect pests occurring in the field or during processing and marketing. In fact, grain legumes suffer heavy quantitative and qualitative losses during storage from the attack of stored product insects. Damage to stored grains and grain products may amount to 5–10% in temperate and 20–30% in tropical zones (Nakakita, 1998), and has approached 50% as reported by Caswell (1981) for cowpeas infested by *Callosobruchus maculatus* (F.). Weevils may attack the seeds during the cropping period in the fields and young larvae are already infesting dry legumes at the harvest. Without a disinfestation treatment immediately after

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harvest, the development of juvenile instars and the emergence of a new generation can cause serious damage to seeds during the storage period. Damaged seeds with emergence holes do not meet quality standards for human consumption in developed countries. Just a few kernels hosting hidden post-embryonic stages can communicate a bad odour to the entire lot of seeds during cooking (Dupuis et al., 2006).

To increase the quality and availability of grain legumes for human consumption, it is often necessary to reduce pest-associated storage losses by applying control measures soon after harvesting. The eradication of infesting pests in stored food around the world is primarily dependent on chemical fumigants like methyl bromide (MeBr) and phosphine. Although effective, they have had undesirable effects on other insect species or non-target organisms, and may have a negative impact on the environment and human health. The ban of methyl bromide since 2005 in developed countries and from 2015 in developing countries (UNEP, 2006) and the increase of insect resistance to phosphine (Benhalima et al., 2004) have emphasized the need to develop practical alternatives to chemical fumigants for control of insect pests in legumes with minimum impact on product quality and environment. In addition, the rising popularity of organic products increases the need for non-chemical postharvest insect control methods. Thermal treatments at high or low temperatures have been investigated extensively as MeBr alternatives for disinfesting stored grains (Casagrande and Haynes, 1976; Loi and Festante, 1989; Kitch et al., 1992; Krishnamurthy et al., 1992; Chinwada and Giga, 1996; Chauhan and Ghaffar, 2002; Dosland et al., 2006; Dupuis et al., 2006; Loganathan et al., 2011). For most stored-product pests, prolonged exposure to temperatures less than 13 °C or higher than 35 °C is lethal. The more extreme the temperature, the more quickly insects die, with death occurring in a few minutes at −20 or 55 °C (Fields, 1992). Thermal disinfestation treatments are relatively easy to apply, leave no chemical residues and may have some fungicidal activity. However, temperature and time combinations required to kill insect pests may meet or exceed those that reduce the viability of seeds, nutrients content, shelf life or technological characteristics (cooking time, texture, hardness and colour after processing, etc.).

The aim of this study was to investigate the effect of thermal treatments (different temperature and time combinations) on physical and biological characteristics of bean, chickpea and lentil.

2. Material and methods

2.1. Legumes and thermal treatments

Plants of *Cicer arietinum* L. (Chickpea), *Lens culinaris* Medik. (Lentil) and *Phaseolus vulgaris* L. (Bean) were grown in Sicily and seeds were harvested during spring and summer 2010. Once collected, sample seeds from a batch of homogeneous seeds were randomly selected and measured. Average seed weight was 52.4, 48.2 and 7.1 g per 100 seeds respectively for bean, chickpea and lentil.

Seven samples of about 200 g for each legume were stored in sealed metal boxes under ambient conditions until thermal treatments were performed. Each sample was treated at low (−18 °C) or high (60 °C) temperature. Heat treatments were made by placing the boxes in a hot air oven at 60 ± 1 °C to maintain the seeds at this temperature for 30, 60 or 90 min. Cold treatments were performed placing the boxes into a freezer at −18 ± 1 °C for 12, 24 or 48 h. At the end of each treatment, the seeds were brought naturally to ambient temperature and stored in this condition until further analysis. One box for each legume was kept at room temperature as a control test. Each treatment was replicated three times.

2.2. Seed vigour and germination

For each species and treatment, four replicates of 50 seeds were placed in Petri dishes on germination paper with 10 ml of distilled water. Seeds were allowed to germinate at 20 ± 1 °C in the dark until the end of the test as stated by official seeds analysis methods (9 days for beans, 8 days for chickpeas and 10 days for lentils) (ISTA, 2006). Germination was considered to have occurred when the radicles were 5 mm long. The seedlings with short, thick and spiral formed hypocotyls and a stunted primary root were considered as abnormally germinated (ISTA, 2006). The number of germinated seeds was recorded every 24 h and mean germination time (MGT) was calculated to assess the rate of germination according to the following formula: $MGT = \sum(g \cdot d)/G$ where g is the number of seeds germinated on day d and G is the total number of germinated seeds at the end of germination analysis.

2.3. Physical properties

Samples of 10 g (weighed exactly) were counted and transferred to measuring cylinders where 50 ml of distilled water were added. Seed volumes were obtained after subtracting 50 ml from the total volume of seeds and water. The cylinders were then covered with aluminium foil and left at room temperature (20 °C) for 18 (bean and chickpea) or 12 h (lentil). After soaking, the seeds were drained, blotted dry with filter paper and weighed. As for dry seeds, swollen seed volume was measured in a graduated cylinder. From these data, weight, volume and density (as g per cubic cm) were calculated for dry and soaked seeds. Seed weight and volume were reported as weight and volume of 1000 seeds in order to average out the small variations occurring at single seed level. Hydration capacity, hydration index, swelling capacity and swelling index were calculated according to Saha et al. (2009). Hydration capacity and hydration index were determined by using the following formulas: Hydration capacity per seed (g seed^{-1}) = $Ws - Wd/N$; Hydration index = $Ws - Wd/Ws$ where Ws is the weight of soaked seeds (g), Wd is the weight of seeds before soaking (g) and N is the number of seeds. Swelling capacity and swelling index were determined by using the following formulas: Swelling capacity per seed (ml seed^{-1}) = $Vs - Vd/N$; Swelling index = $Vs - Vd/Vs$ where Vs is the volume of soaked seeds (ml), Vd is the volume of seeds before soaking (ml) and N is the number of seeds.

After soaking, the soak water was collected. Electrolytes leached into the soaking water were quantified by assessing electrical conductivity (EC) with a digital conductivity meter (Conductivity meter 524, Crison Instruments S.A.) in μS cm^{-1} (Hentges et al., 1991). Soluble solids content (SSC) of the soak water was determined with a digital refractometer (MTD-045nD, Three-In-One Enterprises Co., Ltd.) and expressed as °Brix.

2.4. Cooking quality

The effect of thermal treatments on legume seeds was evaluated by testing also the “degree of cooking” estimating the hardness of cooked seeds after a fixed cooking time (Nasar-Abbas et al., 2008). Seeds of bean, chickpea and lentil (10 g), soaked as reported before, were transferred in beakers (100 ml capacity) covered with aluminium foil containing 50 ml of distilled water (ratio 1:5). Beakers were then placed in a hot air oven (105 °C) for 120, 90 or 60 min, respectively for chickpea, bean and lentil, followed by cooling at room temperature (20 °C) for 30 min. Seed hardness was measured using a digital penetrometer (mod. 53205, TR Snc.) equipped with a flat 2 mm diameter steel punch. Ten cooked beans, chickpeas or lentils were punched individually for each treatment