СОРБЦИОННО СУШЕНЕ НА СЕМЕНА ОТ ПШЕНИЦА, ГРАНИЦИ НА ВЛАГАТА И СЪХРАНИМОСТ
SORPTION DRYNG OF WHEAT SEEDS, MOISTURE LIMITS AND STORABILITY

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Резюме

Извършено е сорбционно сушене на семена от три сорта обикновена пшеница **(**Садово 1, Садово 772 и Катя) и три сорта твърда пшеница (Прогрес, Възход и Белослава). Използван е показателят водна активност (a_w) за илюстриране на процеса сушене при двата вида пшеница. Определена е равновесната влажност в семената при различни параметри на сорбционното сушене. Установени са обхватите на водна активност (a_w) за постигане на максимална съхранимост (**s**) при условията на дългосрочно съхранение в генбанка. Най-добра съхранимост се постига при a_w=0,297 за обикновената пшеница и при a_w=0,197 за твърдата пшеница. Препоръчват се граници за влагата в семената съответно 6,35-6,05% за обикновена пшеница и 6,09-5,82% за твърда пшеница. При тези нива на сушене на семената се постига по-добро съхранение в генбанка и се елиминира отрицателното влияние от замръзване на свободната вода при -18°C.

Abstract

The sorption drying of seeds of three cultivars of bread winter wheat (*Sadovo1*, *Sadovo 772* and *Katia*) and three cultivars of durum wheat (*Progress*, *Vazhod* and *Beloslava*) was carried out. The water activity (a_w) was used for illustration of drying process for both wheat species. The equilibrium moisture content of the seeds was determined at different parameters of the sorption drying. The ranges of water activity (a_w) were determined for achievement of maximum seed storability **(s)** under long-term storage conditions in the gene bank. The best storability was achieved at a_w=0.297 for bread wheat and at a_w=0.197 for durum wheat. The suggested levels of seed moisture were respectively 6.35-6.05% for bread wheat and 6.09-5.82% for durum wheat. At appointed seed drying levels better storability under gene bank conditions was achieved and elimination of the negative effect of free water freezing at -18°C.

Ключови думи: пшеница, сорбционно сушене, водна активност, съхранимост.
Key words: wheat, sorption drying, water activity, seed storability.

INTRODUCTION

The sorption drying of seeds aimed for long-term genebank storage is an obligatory procedure for preliminary seed processing referred to improvement of seed viability in storage. According to the Genebank Standards (Anonimous, 1994) the seed storage is carried out at -18°C and that is the reason for reduction of water content to limits avoiding freezing injury (Cromatry et al., 1982; Stoyanova, 1987; Êameswara et al., 2006). The ability of seeds to survive drying is the main factor for classification of plant species in three groups: orthodox, recalcitrant and intermediate (Roberts, 1973; Hong et al., 1996b; Kameswara et al., 2006). Wheat seeds are suggested as ‘orthodox’ because of their tolerance to drying. The international genebank standards recommend water content of 5±2% (Anonymous, 1994). However, numerous experiments confirm that lower seed moisture could improve storage life of seeds (Ellis at al. 1988, 1989, 1995; Ellis at al., 1990; Ellis at al., 1996; Hong et al., 2005; Perez-Garsia et al., 2007). Later it was presented that the seed storability relate to ‘critical seed moisture’ and the positive effect of drying is available if seed moisture is in equilibrium with ‘critical relative humidity’ of drying environment or a bit higher (Roberts and Ellis, 1989; Ellis et al., 1992; Vertucci and Roos, 1990, 1993 a, 1993 b; Vertucci et al., 1994 a, 1994 b).

The aim of present study is to determine the effect of sorption drying to low seed moisture on seed storability of seeds of bread wheat (*Triticum aestivum* L.) and durum wheat (*Triticum durum* Desf.) intended for long-term genebank storage.

MATERIALS AND METHODS

Seeds of three cultivars bread winter wheat (*T. aestivum* L.): Sadovo 1, Sadovo 772 and Katya, and three cultivars of durum wheat (*T.durum* Desf): Progress, Vazhod and Beloslava were used. Seed samples of each cultivar were divided in 4 sub-samples each of 500g and further processed in a sorption drying cabin supplied with an air dehumidifier Munters MD300. The level of equilibrium seed moisture was achieved at described air relative humidity (*RH*) and room temperature, respectively: 1). 40.2% RH, 24.22°C; 2). 29.7% RH, 27.17°C; 3). 19.7% RH, 24.14°C; 4). 11.6% RH, 17.70°C. The level of equilibrium seed moisture (Me) was achieved at described above air conditions.

The dried seeds were packed up in vacuum PE/AL foil bags and stored further at -18°C for one year in the genebank cold room. Accelerated ageing test was implemented to describe the rate of deterioration as result of treatments: seed desiccation and cold storage. Seed ageing was carried out after re-humidification of stored seeds in humidistat at temperature 25°C and 80% *RH*, while the seed moisture increased to about 15%. Re-humidified seeds were packed in vacuum PE/AL foil bags and set in a thermostat at 40°C for accelerated ageing. Every three days seeds of one bag were tested. Seed germination capacity was determined respectively at 4th and 7th day after placing seeds over the germination bed. The tests of seed moisture content (%) and seed germination capacity were carried out according to the Bulgarian standards 601-85 (Anonymous, 1985). Water activity (a_w) used for better understanding of chemical potential of water in relation to temperature, was calculated as proportion of observed *RH*/100 (Roberts and Ellis, 1989).

RESULTS

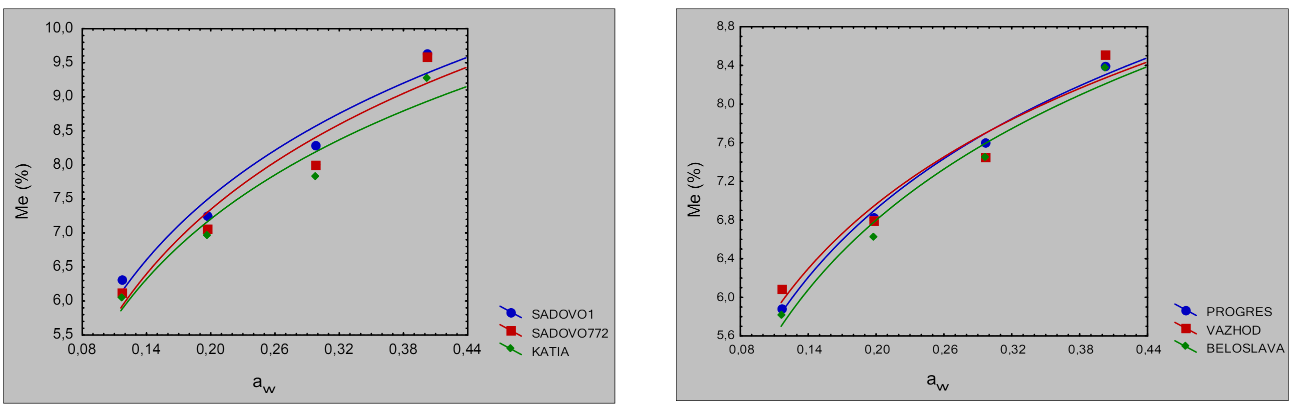
In the present model study the character water activity (a_w) is used to illustrate the relations between drying level and seed storability. As known from theoretical issues a_w is presented as the proportion of partial pressure of water steam over seed surface toward partial pressure of water steam over pure water surface at identical air temperature or more simple as a proportion of air relative humidity to 100 (Roberts and Ellis, 1989; Fontana, 2000; Vulkov, 2006):

$$a_w = p/p_0 = RH/100,$$

where: p – water steam pressure within seeds, p_o – water steam pressure over pure water surface, RH – air relative humidity percent. So identified water activity varies from 0 to 1 and illustrates non-bound water responsible for exchange in surroundings and chemical/biochemical processes in seed metabolism including ageing (Vulkov, 2006). The character a_w in generally presents the chemical potential of water in relation to temperature for every kind of seeds and that is the reason for its wide practical implementation in similar studies (Tarigan et al. 2007; Walters and Engels, 1998).

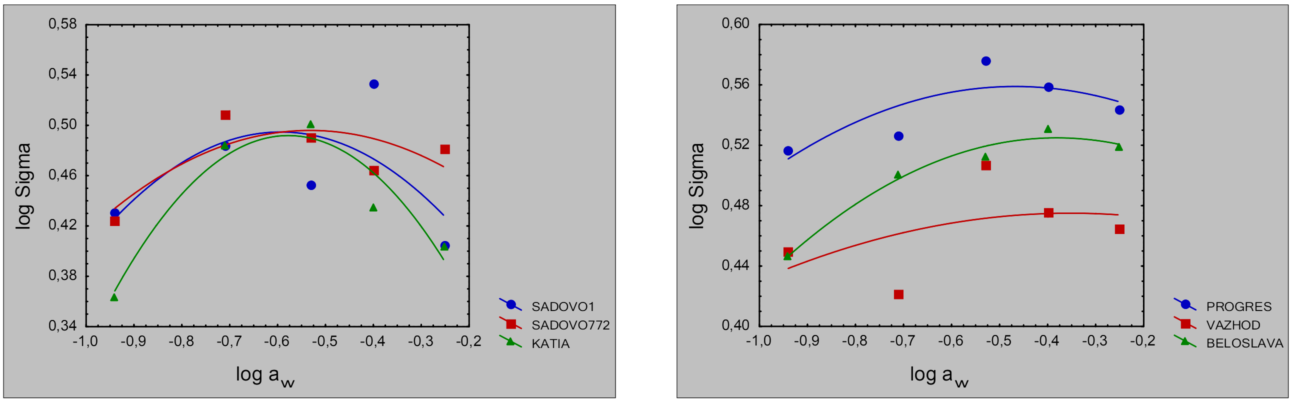
The relationships between equilibrium seed moisture (%) and water activity (a_w) are shown for cultivars of bread and durum wheat (Fig.1). The presented drying curves possess similar shapes. The equilibrium seed moisture (*Me*) of bread wheat cultivars at the high value of a_w=0.402 is between 9.28% to 9.65%. Within the frame of experimental water activity of 0.297 to 0.197 *Me* achieved is respectively between 7.83 – 8.30% and 6.98 – 7.25%. There should be pointed that the values of equilibrium seed moisture (*Me*) in durum wheat cultivars at respective a_w are very close or almost equal. So at a_w=0.402 the equilibrium seed moisture is about 8.38%; at a_w=0.297 the values of *Me* is between 7.45% and 7.60%. The very low equilibrium seed moisture is determined at a_w=0.116 where for bread wheat cultivars varies between 6.35 – 6.05% and for durum wheat between 6.09 – 5.82% (Fig.1). The lowest values of *Me* are detected for cv. Katia (*T.aestivum* L.) and cv. Beloslava (*T.durum* Desf.).

Seed storability (σ) is a character for describing the time for seed survival under storage conditions without changes (Holly et al., 2004; Hong et al., 1996a). In our



Фиг.1. *Графична зависимост между водната активност (a_w) и равновесната влажност (M_e, %) в семена от образци обикновена пшеница - Садово 1, Садово 772 и Катя, и образци от твърда пшеница - Прогрес, Възход и Белослава*

Fig.1. *Graphical relationship between water activity (a_w) and equilibrium moisture content (Me, %) in seeds of bread winter wheat cultivars - Sadovo 1, Sadovo 772 and Katia and of durum wheat cultivars – Progres, Vazhod and Beloslava*



***Фиг. 2.** Логаритмична зависимост между съхранимостта (σ, дни) и водната активност (a_w) при сортове обикновена пшеница (Садово 1, Садово 772 и Катя) и сортове твърда пшеница (Прогрес, Възход и Белослава)*

***Fig. 2.** Logarithmic relationship between seed storability (σ, days) and water activity (a_w) of bread winter wheat culturals (Sadovo 1, Sadovo 772, Katia) and of durum wheat cultivars (Progres, Vazhod, Beloslava)*

study σ is used for evaluation of 'critical seed moisture' – i.e. the limit of seed moisture which further reduction does not improve the seed storability (Walters, 2003; Ellis et al., 1996). As reported in other studies the logarithmic relationship between seed storability and storage conditions (seed moisture and temperature) is valid if seed moisture is higher than critical seed moisture (Ellis et al., 1989). However as also reported previous, the optimum of seed moisture for maximum seed storability could be observed on the basis of an alternative interpretation of 'critical seed moisture' (Walters and Engels, 1998). This approach in our study is implemented using logarithmic relationship between storability of wheat seeds and water activity (Fig.2). As presented in the graphs the maximum of σ is achieved at values log a_w between –0.7 to –0.4. The water activity corresponding to presented logarithmic values is respectively in the range 0.402-0.197. On the basis of data in the graphs the best longevity of seeds is associated with a_w=0.297 for bread wheat seeds and with a_w=0.197 for durum wheat seeds that correspond respectively to log a_w= -0.53 and log a_w= -0.43. Detected values correspond to equilibrium seed moisture of 7.5-8.5% for bread wheat and 6.6-7.0% of durum wheat. There should be pointed that drying to a lower level as well to a higher level is not associated with better longevity of seeds. In our previous study we report that seed moisture reduction up to 6.05-6.30% for *T.aestivum* L. and up to 5.80-6.10 for *T.durum* Desf. is not deleterious (Stoyanova et al., 2007; Desheva et al., 2010). As presented in our previous research the effect of drying to very low seed moisture could retain the initial growth of seedlings, however the izozyme spectra of peroxidases and reproductive capacity of seeds after drying have not been affected (Desheva et al., 2010). As known the critical moisture content for wheat seeds was reported about 5.01-5.5% (Ellis et al., 1990). According to presented suggestions using water activity approach the detected values are higher that presented critical seed moisture. The establishments in the present study show that the best storability of wheat seeds is not necessarily associated with the lower not detrimental level of seed moisture. However there should be pointed that from the practical point of view during seed storage a slight improvement of seed moisture could be expected because of limited permeability of seed containers. Often damages induced by water imbibition of dry seeds are taken as 'drying injures'. That could be one of the reasons for controversial discussion of low seed moisture content in genebank practice (Stoyanova et al., 2007; Desheva et al., 2010).

Taking in the mind the presented above we suggest that drying of wheat seeds to low seed moisture is not detrimental if appropriate approaches for their re-humidification are used. Because of risk for improvement of seed moisture in storage and the negative effect of freezing injuries at -18°C we suggest the drying level slightly lower than theoretically predicted.

CONCLUSIONS

The level of equilibrium seed moisture content of bread and durum wheat is determined during sorption drying at water activity from 0.116 to 0.402. The equilibrium seed moisture achieved at the lower water activity (a_w=0.116) is 6.35-6.05% for bread wheat and 6.09-5.82% for durum wheat. The maximum storability of seeds is predicted at a_w=0.297 for bread wheat and at a_w=0.197 for durum wheat. The best storability of wheat seeds is not necessarily associated with the lower not detrimental level of seed moisture. However it is suggested the drying level slightly lower than theoretically predicted because of risk for seed moisture improvement in genebank storage and the negative effect of freezing injuries at -18°C.

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