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Effect of Different Airflow Speeds Upon the Duration of the Drying Process of High Moisture Pumpkin Seeds after washing

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SUMMARY

High moisture pumpkin seeds (after washing), Australian cultivar Gleissdorf (*Cucurbita pepo* L.) were dried in the laboratory dryer from the initial moisture of 52.3% to the final moisture of ca. 7.5%. Research results indicate that an increase in the airflow speed does not significantly decrease the drying time of seeds, except for the case when the drying air temperature is 40 ^{0}C.

In drying several seed samples, it was established that the optimum airflow speed for seed drying was 0.8 m/s and the air temperature 60 ^{0}C because the drying process was considerably shortened, whereby sticking together of wet seeds was avoided in comparison with airflow speeds of 1.2 m/s and 1.6 m/s. Quality of thus dried seeds is not inferior to that of samples dried at 40 ^{0}C.

Application of high drying air temperatures (80 ^{0}C and 100 ^{0}C) at all three airflow speeds resulted in partly burnt seeds, of dark (scorched) colour and inferior taste. The quality and keeping of such seeds is dubious. The foregoing points to the conclusion that seeds should not be dried with air over 60 ^{0}C and neither at a speed higher than 0.8 m/s.

KEY WORDS

pumpkin seeds (*Cucurbita pepo* L.), drying, air temperature, airflow speed

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Utjecaj različitih brzina strujanja radnog medija (zraka) na trajanje procesa sušenja visoko vlažnih sjemenki buće nakon pranja

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SAŽETAK

Visoko vlažne sjemenke buće (nakon pranja), austrijska sorta Gleissdorf (*Cucurbita pepo* L.), sušene su u laboratorijskoj sušari početne vlage 52,3% na konačnu oko 7,5%. Rezultati istraživanja potvrđuju da se povećanjem brzine strujanja radnog medija (zraka) za sušenje značajno ne smanjuje vrijeme procesa sušenja sjemenki, osim pri temperaturi radnog medija (zraka) za sušenje od 40 °C.

Sušenjem više uzoraka sjemenki definirana je optimalna brzina strujanja radnog medija za sušenje sjemenki od 0,8 m/s, i temperatura radnog medija od 60 °C, jer je proces sušenja značajno skračen, čime je izbjegnuto intenzivno međusobno sljepljivanje mokrih sjemenki u odnosu na brzinu strujanja radnog medija od 1,2 i 1,6 m/s. Kvaliteta ovako osušenih sjemenki nimalo ne zaostaje za uzorcima osušenih na 40 °C.

Primjenom visokih temperatura radnog medija za sušenje (80 °C i 100 °C) za sve tri brzine strujanja radnog medija, sjemenke su djelomično popržene, tamne (nagorjele) boje, lošijeg okusa, te kvaliteta i čuvanje takvih sjemenki je vrlo upitno. Glede navedenog, sjemenke nije opravdano sušiti radnim medijem (zrakom) temperature veće od 60 °C, a niti brzinom strujanja većom od 0,8 m/s.

KLJUČNE RIJEČI

bućine sjemenke (*Cucurbita pepo* L.), sušenje, temperatura zraka, brzina zraka

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INTRODUCTION

In recent years, considerable interest in producing pumpkin seeds intended for their processing into oil has been recorded in Croatia (notably in the regions of Međimurje and Podravina). However, optimal technological solutions for the production and processing of seeds have yet to be found. This particularly applies to drying in the seed processing process.

Pumpkin fruit (*Cucurbita pepo* L.) may be used for many purposes. Besides for production of high quality oil, unhusked and salted seeds are used as nibbling snacks, in the pharmaceutical industry, as a folk remedy, in cooking, etc. Pumpkin pulp is eaten as fruit, it is added to jams and preserves for its pectin content and to juices and baby food for its vitamins, green fruits are eaten as a vegetable, etc. In agriculture, pumpkin pulp is used as animal feed, ensiled with silage maize, applied as natural fertilizer, etc. (Alkaper, 1966., Globelnik, 1971., Grebeščikov, 1950., Rac, 1949.).

There is great demand for the pumpkin variety with seeds without husks, the so called naked seeds. They are in great demand by the domestic oil, chemical and pharmaceutical industries and are also exported (Katić, 1973., Rossrucker, 1992., Schuster, 1977.).

Huskless seeds contain 48-50% of oil. If sown in monoculture, pumpkin may give a yield up to 80 t/ha (Kerep, 1987, Rac, 1949.).

Pumpkins are usually grown as separate crops, but may also accompany other crops, mostly maize. According to Španring (1980.), highest yields are obtained if pumpkins are sown with maize intended for hybrid seed. Pumpkin (*Cucurbita pepo* L.) can be grown in a wide temperature range and is today produced in almost all parts of the world. Since it is especially adjusted to humid climatic conditions, likes sunshine, and is susceptible to frost and lasting low temperatures around the freezing point, pumpkins are sown in this country at the beginning of May (Martin and Leonard, 1969., Popović, 1973.).

The greatest part of continental Croatia has very favourable natural conditions for efficient production of pumpkins intended for processing into cooking oil. Puumpkin oil has a specific smell, flavour, and contains valuable chemical and medicinal components. It is, therefore, classified as "delicatessen oil" (Könemann, 1947., Ploj, 1987., Sito and Pliestić, 1996.).

Major pumpkin producers in Europe include Austria (Steiermark and Karnten), the former USSR countries, Romania, Hungary, Czech Republic, Slovakia and Slovenia. In Croatia, pumpkin is mainly grown in Međimurje and Podravina, where pumpkin production is traditional (Štrucelj, 1981., Topolovec, 1988.).

Results of this research show the extent to which different drying conditions and different airflow speeds influence the time that pumpkin seeds take to dry.

MATERIAL AND METHODS

Samples of pumpkin seeds, *Cucurbita pepo* L. cv. Gleissdorf, contain about 38% water after harvest, which content rises to ca. 52% after washing. Samples were dried in the laboratory dryer in a 5 cm thick layer at air temperatures of 40, 60 and 100 ^{0}C and airflow speeds of 0.8, 1.2 and 1.6 m/s.

Seed moisture was determined at the beginning and at the end of the drying process by the dryer method (standard method). Within the seed moisture limits, other discrete values were determined by *measuring the seed mass* and inserting the known values into the following expression (Katić, 1973.):

$$w_2 = 100 - (M_1 / M_2 (100\text{-}w_1))$$

or

$$M_2 = M_1 * ((100\text{-}w_1)/ (100\text{-}w_2))$$

where: w_1 = initial moisture of the material (%)
w_2 = final moisture of the material (%)
M_1 = initial mass of the material (g)
M_2 = final mass of the material (g)

Air temperature measurements before and after passing through the layer of the material, including measurements of the seed layer temperature, were carried out using specially designed, and incorporated in the regulation system, electroresistant temperature sensors (probes) Pt 100 (ATM-Zagreb) within the dryer (precision ±0.35 ^{0}C).

Ambient temperature was measured with the electroresistant temperature sensor with digital display "Digital-Präzision-Taschen-Thermometer GFH175/MO", precision ±0.1^{0}C. Measuring range: -199.9 to 199.9^{0}C.

Relative humidity of the surrounding air was measured with a digital hygrometer "Digital-Feuchte-Temperaturmebgerät GFTH 95" of relative humidity measurement range 10-95%, precision 0.1% of humidity, and temperature measurement range from –20 ^{0}C to +70 ^{0}C, precision ±0.1^{0}C.

Electronic balance "Tehtnica 6000 D" was used to weigh the seed mass. The balance has a measuring range from 0.1 to 6000 g, weight reading precision ±0.1 gram.

Air speed was measured at the outlet of the dryer cylinder with the digital anemometer "AIRFLOW Edra Five Digital", manufactured by Airflow Developments Ltd. – England. The instrument has a working measuring range from 0.3 to 30 m/s, reading precision 1.5% in linear dependence on the measuring level. Air speed readings are directly displayed on the instrument LCD.

Moisture content of each pumpkin seed was determined first, and then the sample mass, so as to make a 5 cm thick layer in the cylinder. Directly before drying, the gross seed mass together with the cylinder was determined, along with measurements of the ambient temperature and humidity. Drying process started by achieving the desired input temperature and airflow speed through the seed layer. Gross mass (seed mass + cylinder mass) was determined after each 5 minutes of drying up to the end of the drying process. Once the drying process was completed, the net seed mass was determined for each step. The above described expression was used to calculate the water content of seed samples for all steps (every 5 minutes) during the drying process, which are also the main parameters for graphic and mathematical presentation of process curves for all seed samples, as given in the research results. Each sample was dried with three replications and the results of mean values are presented in the graphs.

RESULTS AND DISCUSSION

Research results are presented in Graphs 1-3. As seen from Graph 1, the drying process was considerably protracted if the sample was dried by air having a temperature of 40 ^{0}C and speed of 0.8 m/s, as compared with samples dried at an air speed of 1.2 or 1.6 m/s.

In Graph 2, high moisture samples of pumpkin seeds were dried at the air speed of 1.2 m/s at different temperatures. In comparison with the air speed of 0.8 m/s and air temperature of 40 ^{0}C (Graph 1), this drying process was almost twice shorter.

At the air temperature of 60 ^{0}C, however, the drying process was longer compared to Graph 1. This might be explained by a more intensive sticking together of seeds at higher air speeds, thus forming a layer less pervious to air and taking more time to dry.

Polynomial equations of the curves of drying high moisture pumpkin seeds, cultivar *Gleissdorf*, at the airflow speed of 0.8 m/s:

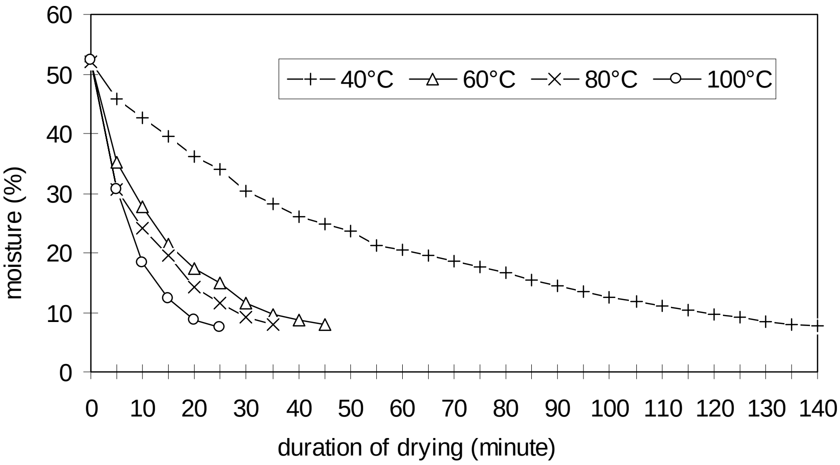
- drying air temperature 40 ^{0}C:
  $w = 51.020 - 3.044\,\tau + 0.055\,\tau^2$
  $t^2 = 0.988$
- drying air temperature 60 ^{0}C:
  $w = 59.347 - 11.874\,\tau + 0.691\,\tau^2$
  $\tau^2 = 0.975$
- drying air temperature 80 ^{0}C:
  $w = 62.296 - 15.370\,\tau + 0.925\,\tau^2$
  $\tau^2 = 0.961$
- drying air temperature 100 ^{0}C:
  $w = 73.860 - 25.460\,\tau + 2.429\,\tau^2$
  $\tau^2 = 0.992$

Polynomial equations of the curves of drying high moisture pumpkin seeds, cultivar *Gleissdorf*, at the airflow speed of 1.2 m/s:

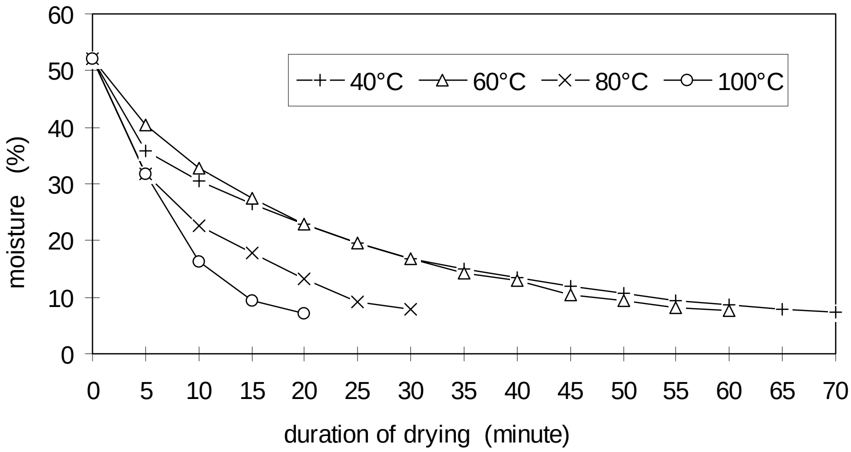
- drying air temperature 40 ^{0}C:
  $w = 51.824 - 6.849\,\tau + 0.269\,\tau^2$
  $\tau^2 = 0.957$
- drying air temperature 60 ^{0}C:
  $w = 56.553 - 8.266\,\tau + 0.356\,\tau^2$
  $\tau^2 = 0.985$
- drying air temperature 80 ^{0}C:
  $w = 66.220 - 18.238\,t + 1.449\,t^2$
  $t^2 = 0.977$
- drying air temperature 100 ^{0}C:
  $w = 79.620 - 30.579\,t + 3.221\,t^2$
  $t^2 = 0.999$

It is clearly evident from Graph 3 that the drying process at the air temperature of 40 ^{0}C and airflow speed of 1.6 m/s was reduced to only 60 minutes, but the same amount of time was required to dry samples at the temperature of 60 ^{0}C. In this case, the airflow speed speeded up the drying process at the air temperature of 40 ^{0}C.

However, such high airflow speed as 1.6 m/s considerably prolongs the drying process at the air temperature of 60 ^{0}C (marked effect of seeds sticking together) in comparison with the airflow speed of 0.8 m/s. Thus, the application of the airflow speed of 0.8 m/s and the temperature of 60 ^{0}C is justified both economically and technologically.



Graph 1. Drying of pumpkin seeds at the airflow speed of 0.8 m/s



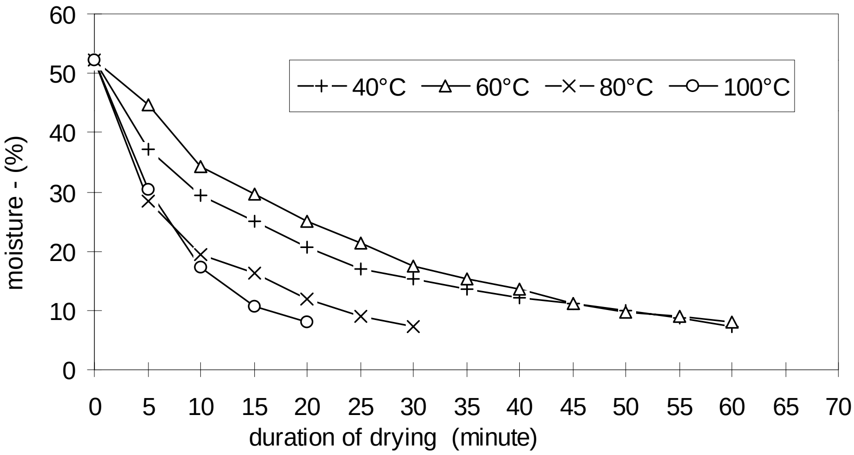
Graph 2. Drying of pumpkin seeds at the airflow speed of 1.2 m/s

Polynomial equations of the curves of drying high moisture pumpkin seeds, cultivar *Gleissdorf*, at the airflow speed of 1.6 m/s:

- drying air temperature 40 ^{0}C:
  $w = 54.582 – 8.383\ t + 0.383\ t^2$
  $t^2 = 0.961$
- drying air temperature 60 ^{0}C:
  $w = 58.502 – 8.266\ t + 0.345\ t^2$
  $t^2 = 0.982$
- drying air temperature 80 ^{0}C:
  $w = 66.234 – 19.660\ t + 1.650\ t^2$
  $t^2 = 0.953$
- drying air temperature 100 ^{0}C:
  $w = 78.500 – 29.954\ t + 3.186\ t^2$
  $t^2 = 0.998$

Katić (1973.) recorded an increase of water content to 45% in common dry pumpkin seeds, bought from individual producers with a water content up to 10%, after their intensive stirring during washing for 45 minutes. This author, however, also stresses that, if wet seeds are centrifuged at a revolution speed of 32 m/s, the water content decreases to ca. 35%, thereby reducing the drying costs by ca. 40%. Seeds were dried in a “Scolari” dryer with a stirrer. The drying air temperature was 60 ^{0}C and the drying process, without centrifuging, to the final moisture of about 8% lasted 90 minutes. However, the drying process of seeds that were previously centrifuged for 4 minutes lasted only 70 minutes.

Kerep, Nadica (1987.), investigated the possibility of drying common seeds with husks in the continual operation dryer “Goldsaat” with drying air of 78 ^{0}C. When drying started, the seed layer was 21 cm thick at the beginning, 16 cm in the middle, and only 12.7 cm at the end of the dryer. The active, perforated drying surface where the seeds were dried was 24 m^2. The dryer has a stirrer with spirally set rubber blades, which is used for mixing and transport of seeds during the drying process. Seed moisture was 9.3% before drying, 45.3% after washing, 44.2% after straining without centrifuging, and 5.4% after drying. In this case, the straining procedure did not produce an effect equal to



Graph 3. Drying of pumpkin seeds at the airflow speed of 1.6 m/s

centrifuging. The drying process rendered a capacity of 577 kg/h of dried seeds while 400 kg/h of water was separated, with specific thermal energy consumption of 5999 kJ/kg. The spent specific energy consumption is too high, dryer capacity is far below the nominal, which is attributed to inadequate maintenance of worn dryer parts. The particularly applies to the worn-out condition of stirrer blades, because of which the seeds remained on the perforated plate and were dried up, too much energy was spent and the drying capacity was reduced.

Rossrucker (1992.) dried naked seeds in a dryer for fruit and vegetables using drying air of 40, 50, 60 and 70 ^{0}C in the quantities between 1500 and 300 $m^3/m^3/h$ (1m^3 of air per 1 m^3 of seeds per hour). Initial seed moisture ranged from 35% to 40%, after drying 8%. The seed drying process at the air temperature of 70 ^{0}C and an airflow of 3000 $m^3/m^3/h$ lasted about 5 hours while that at the drying temperature of 40 ^{0}C took 11 hours.

Sito and Pliestić (1996.) studied the factors affecting the drying process of naked pumpkin seeds in a small laboratory dryer. Seeds with initial moisture of 38% (without washing) were dried to the final moisture of about 8-10%. The drying process proceeded at different temperatures and airflow speeds. The drying air temperature had a direct influence on the duration of the drying process, as well as on the quality of dried seeds. The higher the air temperature, the shorter was the drying process, however up to 80 ^{0}C. Airflow speed had no marked influence on the drying time, except in the case of the air temperature of 40 ^{0}C. *Sticking together* of seeds was recorded during the drying process, especially in its first part, because the seeds were not previously washed.

Comparison of the results obtained in this research with those of the cited authors points to the conclusion that the temperature of the air used to dry seeds is the common, decisive factor for the duration of the drying process, and particularly the quality of dried seeds.

Processing of the research results resulted in the polynomial equations of the second order and graphs, defining the drying process of pumpkin seeds at different temperatures and airflow speeds.

CONCLUSION

Drying of seeds at different airflow speeds at different temperatures of the drying air revealed that the optimum airflow speed was that of 0.8 m/s and the drying air temperature of 60 ^{0}C. In that case, the drying process was considerably shortened, thereby avoiding intensive sticking together of high moisture seeds, in comparison with airflow speeds of 1.2 and 1.6 m/s, and the quality of dried seeds was not inferior to that of samples dried at 40 ^{0}C.

Temperature of the drying air had a decisive effect on the duration of the drying process. The drying process was significantly shortened by increasing the temperature of the drying air. This holds for air temperatures up to 80 ^{0}C. High air temperatures (over 60 ^{0}C and up to100 ^{0}C), however, impair the quality of seeds, which become partly burnt, of dark (scorched) colour and inferior taste. Keeping of such seeds is dubious.

For each sample, a graphic presentation is given for moisture reduction (w), in dependence on time (t), during seed drying, as well as the appertaining trinomial equations. The relation between these two elements (w, t) is very significant in almost all seed samples with respect to very high determination coefficients (r^2).

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