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Dehydration and Drying Characteristics of Gingers Using Dehydrating Agent by Dextrose Equivalent and Molecular Weight Condition

Hyun-Seok Lee[1], Ki-Hyun Kwon[1†], Byeong-Sam Kim[1], Jin-Woong Jeong[1],
Jong-Hoon Kim[1] and Jung-Min Sung[1]
[1]*Korea Food Research Institute, Sungnam 463-746, Korea*

포도당 당량과 분자량 조건별 탈수제를 적용한 생강의 탈수와 건조 특성

이현석[1] · 권기현[1†] · 김병삼[1] · 정진웅[1] · 김종훈[1] · 성정민[1]
[1]한국식품연구원

Abstract

We examined variations in ginger dehydration and recovery rate upon use of dextrose of different equivalence values. The dehydration rate varied with dextrose equivalent and the dehydration rate increased as the equivalence value increased. Both dehydration and recovery rates varied with dextrose molecular weight. Moisture content was lowest in samples prepared by freeze-drying, and neither dextrose equivalent nor molecular weight affected moisture level. Upon color analysis, ginger dried using dextrose varying in equivalence and molecular weight was similar in color to the original material, unlike ginger dried by other methods. Hot-air-dried ginger scored lowest in all sensory tests, compared with ginger prepared by molecular press dehydration using dextrose varying in equivalence and molecular weight. With respect to the appearance of ginger, freeze-dried samples were optimal, but molecular press dehydration yielded samples that scored best upon overall evaluation. When all quality evaluation items were taken together, molecular press dehydration resulted in a better quality product than the older hot-air or freeze-drying methods.

Key words : dextrose equivalent, molecular weight condition, maltodextrin, polyethylene glycol

Introduction

Ginger (*Zingiber officinale* Roscas) is native to tropical and subtropical area including Egypt and Iraque and is a rhizome of perennial herbaceous plant belonging to Zingiberaceae that has been grown from the prehistoric times (1). It acts as a spice and has functions for various medical actions and protective actions for a living body as it contains unique flavor and taste (2,3). Seosan, Chungchengnam-do and Wanju, Jellabug-do area produce 40,000 tons of gingers, which account for 95.6% of the total production (4). Gingers have physiological disorders below 10℃ and germinate at temperatures above 18℃, which makes it difficult to store and dry for long term storage (5). Typical drying methods used for vegetables and fruits among food to increase the storage period are heated-air drying, freeze drying, and osmotic drying (6). Heated-air drying is a simple treatment and one of the economic methods among the existing drying methods but can loose color, nutritive components and taste by the high temperature during the drying period and cause a resiliency problem by the rapid contraction of the cellular tissue (7). Freeze drying makes up for the shortcoming of heated-air drying with less loss of taste, flavor component and functional component and has advantage not to destruct much cellular tissues. Osmotic drying minimizes the damage of color, taste and flavor by the heat and prevents discoloration during the drying. It also is a drying method to remove sour

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[†] Corresponding author. E-mail : kkh@kfri.re.kr,
Phone : 82-31-780-9258, Fax : 82-31-780-9144

taste and increase sweetness enhancing the preference but it can reduce the dehydration efficiency by the separation of cell membrane and can cause degradation of sample quality (9). Recently, molecular press dehydration (10), a new drying method using the cytorrhysis by the pressure generated between the cell walls without causing separation of cell membrane is being utilized by using maltodextrin to supplement the impregnation soaking process with the solute bigger than the size of sample hole. This molecular press dehydration was also reported by Lee et al. (11) who studied quality characteristics of ginseng powder. Therefore, in this study, the drying method of molecular press dehydration was applied to dry gingers different from previous drying methods to prepare drying characteristics by the maltodextrin equivalent which was applied as the dehydrator, and to prepare drying characteristics by the molecular weight condition of the Poly Ethylene Glycol. The possibility to maximize the dehydration condition and the quality evaluation was also conducted in the study.

Materials and Methods

Experimental and materials

The ginger used in the experiment was harvested in 2009 in Seosan City, Chungcheongnam-do (producer: Seosan Ginger Cluster Agency). The ginger prepared by Seosan Agricultural Cooperative was purchased on the date of experiment at the Hanaro Mart in Seongnam. Only product with good appearance was selected and screened out gingers with any damage or decay. The Maltodextrin (Maltodextrin, Dae Sang Co., Seoul, Korea) product which was used as dehydrator were selectively purchased with moisture content (%) less than 10.0%. Maltodextrin (Maltodextrin, Sigma Co., St. Louis, MO, USA) was purchased according to Dextrose Equivalent and PEG (Polyethylene glycol) 200, PEG 400, PEG 600, PEG 4000 molecular dehydrating agent (Polyethylene glycol, DAE JUNG Chem. Co., Siheung, Korea) and PEG 1000, PEG 2000, PEG 8000 molecular dehydrating agent (Polyethylene glycol, Yakuri Pure Chem. Co. Kyoto, Japan) were used according to molecular equivalent.

Pretreatment of samples

To apply in the experiment, 200 g of ginger sample sliced in 1-1.5mm was applied to powder type dehydrating agent maltodextrin with D.E. values (D.E. 4~7, 9~12, 13~17, 16.5~19.5). Then, 80% (w/w) in proportion to weight was added and well mixed in LPDE container and hydrated for 7 hours with the velocity of 2-3 rpm. In the same manner, different molecular weights were applied (PEG 200, 400, 600, 1000, 2000, 4000, 8000). After hydration, the samples of dried matter and hydrated liquid was separated by centrifugation at 3000 rpm for 5 minutes. The hydrated matter was stored and dried in the incubator at 30℃. For freeze drying, 1 kg was mounted on the freeze drying shelf and was frozen at -20℃ for 48 hours, followed by freeze drying in the free dryer (PVTFD100R, Ilshin Lab Co., Yangjugun, Korea) for 72 hours(heating device -40℃, 999mm torr). For heated-air drying, heated-air dryer (HK-DO1000F, Korea General Equipment Manufacturing, Hwaseong, Korea) was used at 60℃ with 1 kg mounted on the rack(wind velocity 0.5m/sec). Thereafter, all dried samples were used in the product analysis.

Dehydration rate

For Dehydration rate, modified Kim et al's method (12) was used. After mixing the input sample and dehydrating agent, the mixture was centrifugated in proportion to weight and the rate of the hydrated liquid was calculated using the following equation.

$$Dehyrationrat(\%) = \frac{liquid\,after\,centrifugation}{sample + dehydrating\,agent} \times 100 \;...... (Eqn2)$$

Recovery rate

For recovery rate, 50 mL of distilled water was added to dehydrated dry sample 1 g in 100 mL beaker and soaked at 25℃ water bath for 60 minutes and reabsorbed. Then the sample was taken out of the bath and moisture was removed, followed by measurement of weight and the rate of recovery, which was calculated using the following equation (12).

$$Recoverytate(\%) = \frac{reabsorbed\,sampe\,weight - dehydrated\,dry\,sample\,weight}{reabsorbed\,sampe\,weight} \times 100 \;...... (Eln2)$$

Moisture content

For moisture content, approximately 5 g of sample was taken in a constant weight dish for each treatment and dried in the dry oven (Korea General Equipment Manufacturing, Korea). Experimental was conducted with 105℃ drying method and the drying was continued until constant when the average and standard deviation was determined.

Color

The color measurement of the dry cut surface of the gingers by molecular press dehydration, heated-air dried and freeze dried gingers was conducted using Colorimeter (CR-300 Minolta Chromameter, Minolta Camera Co., Osaka, Japan) modified with standard plate (L = 97.47, a = -0.02, b = 1.67). Each sample group was repeatedly measured three times for Hunter L (+White, -Black), a (+Red, -Green) and b (+Yellow, -Blue) followed by analysis of values. All samples were measured three times and the averages and standard deviations were obtained with the results.

Sensory evaluation

Sensory evaluation was conducted with 10 panels, average age of 20-30, who were selected considering reliability, health and interest in the experiment among the researchers in the Sensory Laboratory of the Korea Food Research Institute. Dextrose equivalent and hydration rate by molecular weight and the heated-air dried and freeze dried samples were compared. The purpose and objective of the experiment was explained to them and pre-training was offered on the sensory evaluation for them to understand detail items prior to the evaluation. Sensory evaluation was performed between 3:00 pm and 4:00 pm and each ginger sample was presented on a white plate with 10 cm diameter. For each evaluation item of each process, 9 point evaluation was conducted with Excellent (9 points), Good (7 points), Fair (5 points), Poor (3 points), Very Poor (1 point) and the average was presented. Sensory evaluation was performed by the experimental process on the color, flavor, taste, texture and overall acceptability of the condition.

Statistical analysis

Statistical analysis was repeatedly performed more than three independent times and the results were presented in average and ± standard deviation. SAS 6.0 for windows program (13) was used to verify the significance of the experimental groups, and the significance was verified with Duncan's multiple range test (DMRT) at $p < 0.05$ and $p < 0.001$ levels.

Results and Discussion

Dehydration rate and recovery rate by dextrose equivalent weight

The variance of dehydration rate by the dextrose equivalent weight using the molecular press dehydration is shown in Fig. 1 and the recovery rate is presented in Fig. 2. The difference between the dextrose equivalent (D.E. 4~7, D.E. 9~12, D.E. 13~17, D.E. 16.5~19.5) of the dehydrating agent was identified and the dehydration rate varied depending on the dextrose equivalent, showing the increasing trend of hydration rate with higher equivalent. Except the dextrose equivalent (D.E. 4~7) at the time initial dehydration passed one hour, significance was valid in the error range ($p<0.001$). Then, as the dehydration passes 2~6 hours, dehydration rate increased with higher equivalent. In the 6~7 hour dehydration, no significant difference was noticed and showed stable changes. This agrees with the studies by Kim et al (12) and Kim et al (14) who reported if maltodextrin

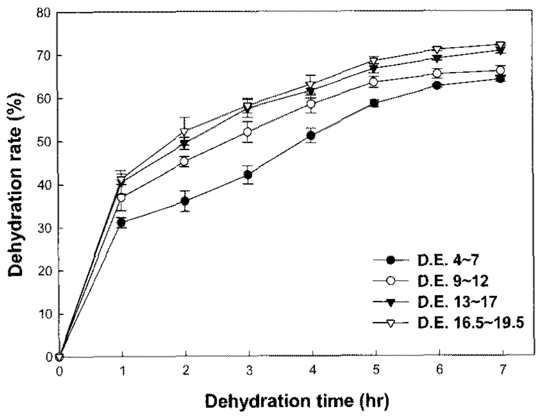

Fig. 1. Change in dehydration rate during drying of ginger by dextrose equivalent condition.

*D.E.(Dextrose equivalent) = Direct reducing sugar (glucose) / total solid × 100

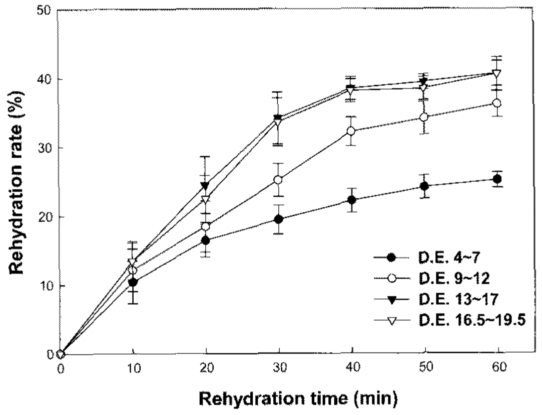

Fig. 2. Change in rehydration rate during drying of ginger by dextrose equivalent condition.

*D.E.(Dextrose equivalent) = Direct reducing sugar (glucose) / total solid × 100 dehydrating agent was added according to the content, the dehydration was moderate after a certain period of time. In the final molecular press dehydration, the dehydration rate increased as the dextrose equivalent is higher. D.E. 13~17 and D.E. 16.5~19.5 were significant within the error range ($p < 0.001$). These results showed same trend as reported by Choi et al (15) in that the difference in the dextrose equivalent caused change of dehydration rate. For recovery rate, dehydrated ginger was rehydrated and measured with the samples collected every 10 minutes. The recovery rate was different depending on dextrose equivalent and as the equivalent becomes greater the recovery rate showed increasing trend. At the point initial rehydration time passed 10 minutes, significance was observed within the error range despite of the dextrose equivalent ($p < 0.001$). Then, as the rehydration time passed 20~60 minutes, the recovery rate increased as the equivalent was greater. Modest recovery rate was noticed with lower dextrose equivalent while the recovery rate was higher with greater dextrose equivalent. The recovery rate of the recovered ginger by the rehydration of final molecular press dehydration process showed increased recovery rate with higher dextrose equivalent and the D.E. 13~17 and D.E. 16.5~19.5 were significant withing the error range. The study by Lim (16) also indicated same results as found in this research. This is similar to the experimental results of dehydration rate. In the molecular press dehydration method, dehydration rate and recovery rate are believed to have correlations.

Dehydration rate and recovery rate for each molecular weight condition

The variance of dehydration rate for dehydrating agent with different molecular weight using molecular press dehydration are shown in Fig. 3 and the recovery rate is presented in Fig. 4. The difference of molecular weights (PEG 200, 400, 600, 1000, 2000, 4000, 8000) of dehydrating agent are identified. The dehydration rate was different depending on the molecular weight of the dehydrating agent and as the molecular weight became greater, the dehydration rate clearly showed increasing trend. At the point initial dehydration time passed 1 hour, dehydration rate started to increase. In case of low molecular weights (PEG 200, 400, 600), dehydration progressed by plasmolysis. On the other hand, greater molecular weights (PEG 1000, 2000, 4000, 8000) caused molecular press dehydration phenomenon (cytorrhysis) and the dehydrating agent with high molecular weigh resulted in higher dehydration rate compared to lower molecular weight. These results were reported by Choi et al (15) and Choi (17) who studied that moisture loss solute penetration rate increased as the molecular weight increased. In the dehydration process, dehydration rate increased as the molecular weight becomes greater and the PEG 4000 and PEG 8000 was significant within the error range ($p < 0.001$). In the case of the recovery rate, recovery rate changed depending on the difference of the molecular weight and as the molecular weight becomes greater the recovery rate clearly showed increasing trend. As reported in the studies by Kim et al (14) and Kim et al (18), at the point initial rehydration time passed 10 minutes, recovery rate started to increase but the rate was constant after a certain period of time. For the recovery rate with low molecular weights (PEG

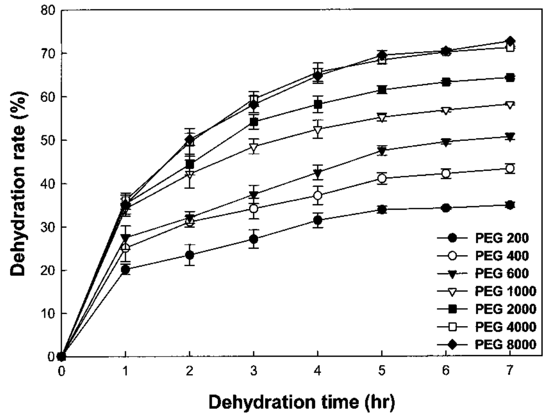

Fig. 3. Change in dehydration rate during drying of ginger by molecular weight condition.

*PEG = Poly Ethylene Glycol

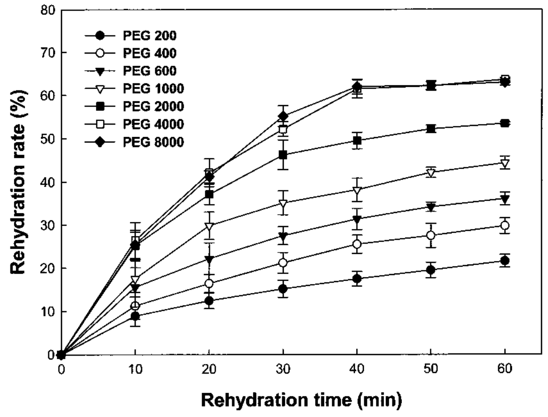

Fig. 4. Change in rehydration rate during drying of ginger by molecular weight condition.

*PEG = Poly Ethylene Glycol

200, 400, 600), the recovery process of the dehydrated matter from the dehydration was progressed by plasmolysis and modest. For higher molecular weights (PEG 1000, 2000, 4000, 8000), the recovery rate of the dehydrated matter which was progressed by molecular press dehydration phenomenon (cytorrhysis) was higher and the dehydration rate of the dehydrating agent with high molecular weight showed higher dehydration rate compared to that of the lower molecular weight. As the molecular weight increased, the recovery rate increased and the PEG 4000 and PEG 8000 were significant within the error range same as dehydration rate ($p < 0.001$). Choi (17) reported that moisture loss increased and solute penetration rate decreased as molecular weight increased and it is believed the rate varies depending on the molecular weight.

Table 1. The sensory characteristics of hot-air dried, freeze dried and molecular press dehydration method using ginger

Treatment*	Appearance	Color	Flavor	Texture	Acceptability
HD	$4.9\pm1.28^{b**}$	5.1 ± 1.19^{b}	5.9 ± 1.19^{a}	5.1 ± 0.73^{a}	5.3 ± 0.82^{b}
FD	7.2 ± 1.31^{a}	4.9 ± 1.52^{b}	5.7 ± 1.88^{a}	6.0 ± 1.76^{a}	6.5 ± 1.26^{a}
MPD (D.E. 13~17)	5.7 ± 1.13^{b}	6.7 ± 1.25^{a}	6.7 ± 1.24^{a}	6.2 ± 1.12^{a}	6.7 ± 0.98^{a}
MPD (D.E. 16.5~19.5)	5.8 ± 0.80^{b}	6.7 ± 1.06^{a}	6.5 ± 1.23^{a}	6.2 ± 1.02^{a}	6.6 ± 0.69^{a}
MPD (PEG 4000)	5.8 ± 1.21^{b}	6.7 ± 1.24^{a}	6.6 ± 1.03^{a}	6.1 ± 1.22^{a}	6.7 ± 1.26^{a}
MPD (PEG 8000)	5.7 ± 0.93^{b}	6.7 ± 0.98^{a}	6.6 ± 1.11^{a}	6.0 ± 1.11^{a}	6.7 ± 1.14^{a}

*HD : Hot-air drying, FD : Freeze drying, MPD : Molecular press dehydration method, D.E. : Dextrose Equivalent, PEG : Polyethylene glycol.

**Means with different letters with a row are significantly different from each other p<0.05 as determined by Duncan's multiple range test.

Table 2. The moisture contents of ginger prepared by hot-air dried, freeze dried and molecular press dehydration method

Treatment*	Moisture contents(%)
HD	$8.1\pm0.1^{b**}$
FD	7.4 ± 0.1^{c}
MPD (D.E. 13~17)	8.9 ± 0.1^{a}
MPD (D.E. 16.5~19.5)	8.8 ± 0.2^{a}
MPD (PEG 4000)	8.8 ± 0.1^{a}
MPD (PEG 8000)	8.8 ± 0.1^{a}

*HD : Hot-air drying, FD : Freeze drying, MPD : Molecular press dehydration method, D.E. : Dextrose Equivalent, PEG : Polyethylene glycol.

**Means with different letters with a row are significantly different from each other p<0.05 as determined by Duncan's multiple range test.

Moisture content

The moisture content of the ginger powder prepared by the heated-air drying and freeze drying applying the molecular press dehydration by the dextrose equivalent and molecular weight is presented in Table 2. The results showed that heated-air drying had 8.1±0.1%, freeze drying 7.4±0.1% and the moisture content of the ginger sample applying the molecular press dehydration was 8.8~8.9%, similar in all conditions ($p < 0.05$). In the study of Shin et al (19), the reason for the lower moisture content of the ginger by freeze drying was reported it is due to the fact the absorption characteristics for the temperature is distinct than the heated-air dried power and because the porosity of the particles are bigger by its characteristics. In case of ginger powder applying the molecular press dehydration, the moisture content and the moisture activity was observed relatively high as the process does not use heat and the water-soluble substances applied to the surface moisture of the dried matter by the cell contraction occurred during the dehydration.

Color

In the color analysis of ginger samples, the brightness was 64.17 and 66.19, lower than original sample but the brightness at the condition of the heated-air drying and freeze drying was higher with 80.21 and 87.27, respectively. Also, the b value for the ginger samples for dehydrating agent and treated with recycled dehydrated water showed 30.11, 29.45. At the heated-air drying and freeze drying conditions, it was 17.29, 23.85, respectively, which indicates the ginger sample applying the molecular press dehydration process maintains the color of the original (Fig. 5). This represents similar results as reported by Kim et al (18) who showed there is no significant difference for the maltodextrin treated by different concentrations. However, the heated-air drying and freeze drying resulted in color changes, For heated-air drying, browning phenomenon occurred by the high temperature than the molecular press dehydration changing the original color of the ginger. This is similar to the research results by Jeong et al (20) who reported heated-air drying can change colors. In addition, if ginger is continuously frozen at a low temperature during the freeze drying process, it can degrade the quality of ginger with the damage to the cell wall by ice crystals (21). Compared to freeze drying and heated-air drying, the molecular press dehydration process with the addition of dehydrating agent decreased the damage to the cell wall (10) and resulted in stable L, a, and b values.

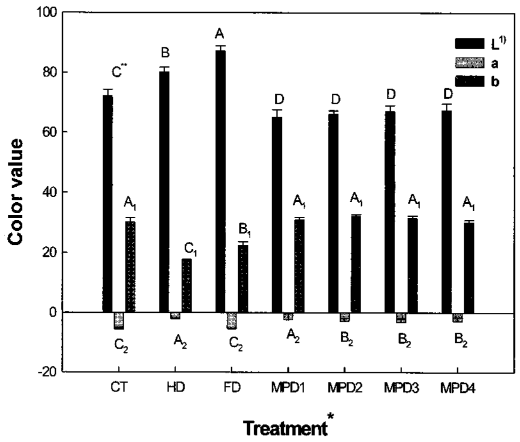

Fig. 5. Hunter color values of ginger prepared by hot-air dried, freeze dried and molecular press dehydration method.

1)L(+Lightness), a(+Redness, -Greenness), b(+Yellowness, -Blueness)

*CT : Fresh ginger, HD : Hot-air drying, FD : Freeze drying, MPD1 : Maltodextrin(D.E. 13~17), MPD2 : Maltodextrin(D.E. 16.5~19.5), MPD3 : Poly Ethylene Glycol 4000, MPD4 : Poly Ethylene Glycol 8000

**Means with different letters with a row are significantly different from each other p<0.05 as determined by Duncan's multiple range test.

Sensory evaluation

For sensory evaluation of the dextrose equivalent of the dehydrating agent, molecular weight, molecular press dehydrated matter in slice condition by the reaction time, and the quality of heated-air drying and freeze drying types, appearance, color, flavor, texture and overall acceptability were evaluated by trained 10 sensory panels. For each evaluation item for each process, 9 point evaluation was conducted with Excellent (9 points), Good (7 points), Fair (5 points), Poor (3 points), Very Poor (1 point) and the average and standard deviation were presented (Table 1). With respect to appearance, the ginger with freeze drying showed highest value of 7.2±1.31. The dehydrated dried matters by the heated-air drying, dextrose equivalent and molecular weight did not show any significant difference ($p < 0.05$) but ginger with heated-air drying had lowest value. This is related to the contraction phenomenon during the drying period. According to the report by Azian et al (22), cell wall can be broken by contraction of the starch component in the tissue cell of the steam dried gingers. In case of color, the dehydrated matter by molecular press dehydration was 6.7±1.25, 6.7±1.06, 6.7±1.24, and 6.7±0.98 which is better compared to those of the heated-air drying and freeze drying. In addition, the dehydrated matter by molecular press dehydration showed better flavor than the ginger by heated-air drying and freeze drying. This results indicates that the process applying the molecular press dehydration maintains color and flavor. In terms of texture, the points for heated-air drying 5.1±0.73 and freeze drying 6.0±1.76 were relatively lower than the ginger by molecular press dehydration but no significant difference was observed ($p < 0.05$). In the overall preference, the molecular press dehydration applying freeze drying, dextrose equivalent and dehydrating agent for each molecular weight showed excellent results with no significant difference except the ginger by heated-air drying ($p < 0.05$). Kim et al (12), Kim et al (14) and Kim (18) also reported better samples with the molecular press dehydration process. In overall, the ginger with heated-air drying was evaluated as the lowest and the ginger by freeze drying and molecular press dehydration were highly evaluated. The ginger sample prepared by the molecular press dehydration applying freeze drying, dextrose equivalent and dehydrating agent for each molecular weight is determined to be relatively good.

요 약

포도당 당량에 의한 탈수율과 복원율의 변화에서는 포도당 당량에 차이에 따라 탈수율은 달라졌으며 당량이 커질수록 탈수율과 복원율이 증가하는 경향을 나타내었다. 분자량에 의한 탈수율과 복원율에 변화에서는 분자량이 다른 탈수제 차이에 따라 탈수율과 복원율이 달라졌으며 분자량이 커질수록 포도당 당량과 같이 뚜렷하게 탈수율이 증가하고 복원율이 높게 나타났다. 수분함량은 동결건조한 시료가 가장 낮았으며 당량과 분자량에 따른 차이는 나타나지 않았다. 색도에서는 D.E.와 분자량(PEG)을 적용한 생강이 다른 건조방법의 색도보다 원물과 유사하였다. 관능평가를 통하여 포도당 당량과 분자량별 탈수제를 적용한 분자압축 탈수건조한 생강시료를 비교 하였을 때 모든 항목에서 열풍건조가 가장 낮았고 외관의 경우에서는 동결건조한 시료가 우수하였지만 전체적인 평가에 있어서 분자압축 탈수건조한 생강이 가장 우수하였다. 이 처럼 모든 품질평가 항목의 결과를 통하여 분자압축 탈수건조가 이전에 열풍건조와 동결건조보다 품질이 우수하였다.

References

1. Lee CB. (1979) Illustrated Flora of Korea. Hyangmoon Publish Co., Seoul, Korea, p.231-231
2. Kang JH, Ahn BW, Lee DH, Byun HS, Kim SB, Park YH. (1988) Inhibitory effects of ginger and garlic extracts on the DNA damage. Korean J. Food Sci. Technol., 20, 287-292

3. Park KY, Kim SH, Suh MJ, Chung HY. (1991) Inhibitory effects of garlic on the mutagenicity in salmonella assay system and on the growth of HT-29, human colon carcinoma cells. Korean J. Food Sci. Technol., 23, 370-374
4. Chung TY, Jeong MC, Lee SE, Kim DC, Kim OW. (1996) Morphological characteristics of ginger depending on habitat. Korean J. Food Sci. Technol., 28, 834-840
5. Das P, Sarma SK. (2001) Drying of ginger using solar cabinet dryer. J. Food Sci. Technol., 38, 619-621
6. Janjai S, Srisittipokakun N, Bala BK. (2008) Experimental and modeling performances of a roofintegrated solar drying system for drying herbs and spices. J. Food Eng., 33, 91-103
7. Mazza G. (1983) Dehydration of carrots (Effects of pre-drying treatments on moisture transport and product quality). J. Food Technol., 18, 113-123
8. Krokida MK., Maroulis ZB, Saravacos GD. (2001) The effect of the method of drying on the color of dehydrated products. Int. J. Food Sci. Technol., 36, 53-59
9. Ponting JD. (1973) Osmotic dehydration of fruits-recent modifications and applications. Proc. Biochem., 8, 18-20
10. Soe HC, Yu MS. (2004) Molecular press dehydration of plant tissues using soluble high molecular weight dehydrating agent. Korea Patent No.10-0444843
11. Lee HS, Kwon KH, Jeong JW. (2009) Quality characteristics of ginseng powder using molecular press dehydration method. Korean J. Biosystems Eng., 34, 155-160
12. Kim MH, Kim MK, Yu MS, Song YB, Seo WJ, Song KB. (2008) Drying of green pepper using maltodextrin. Korean J. Food Preserv., 15, 694-698
13. SAS (1995) SAS User's Guide. Statistical Analysis Systems Institute Inc., Cary, NC, USA
14. Kim MK, Kim MH, Yu MS, Song YB, Seo WJ, Song KB. (2009) Dehydration of carrot slice using polyethylene glycol and maltodextrin and comparison with other drying methods. J. Korean Soc. Food Sci. Nutr., 38, 111-115
15. Choi DW, Shin HH, Kim JG. (2006) A study of dewatering phenomena of potato slice cytorrhysed by high molecules. J. Korean Soc. Food Sci. Nutr., 19, 358-365
16. Lim EJ. (2008) Optmization of molecular press dehydration drying process of ginseng and its application. Mister thesis. Korea Polytechnic University, Siheung, Korea
17. Choi DW. (1998) Study on dewatering and impregnation soaking process of potato. Ph D thesis, Yonsei University, Seoul, Korea
18. Kim MH, Kim MK, Yu MS, Song YB, Seo WJ, Song KB. (2009) Dehydration of sliced ginger using maltodextrin and comparison with hot-air dried and freeze-dried ginger. Korean J. Food Sci. Technol., 41, 146-150
19. Shin HK, Hwang SH, Youn KS. (2003) Absorption characteristice and prediction model of ginger powder by different drying methods. Korean J. Food Sci. Technol., 35, 211-216
20. Jeong JW, Seong JM, Park KJ, Lim JH. (2007) Quality characteristics of semi dried red pepper(Capsicum Annuum L.) using hot-air drying. Korean J. Food Preserv., 14, 591-597
21. Krokida MK, Maroulis ZB, Saravacos GD. (2001) The effect of the method of drying on the color of dehydrated products. Int. J. Food Sci. Technol., 36, 53-59
22. Azian MN, Kamal AAM, Azlian MN. (2004) Changes of cell structure in ginger during processing. J. Food Eng., 62, 359-364

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