Effect of osmotic dehydration on antioxidant compounds and sensory acceptance of vegetable snacks

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ABSTRACT: Dehydration of vegetables is a process commonly used to preserve the product. However, collapse of the structure, discoloration and beneficial compound loss are frequent quality problems. The combination of osmotic dehydration (OD) and hot air drying is widely used process that could improve the qualities of dried fruit and vegetable products. The objective of this work was to study the effect of OD using salt solution as a pretreatment on certain properties of pumpkin, sweet potato and mushroom snacks. Pumpkin, sweet potato, mushroom pieces were soaked in 5% salt solution (sodium chloride) for 30 and 60 mins. The vegetables were then dried at 60°C until their a_w were 0.35-0.45. The unsoaked vegetables were also served as control samples. The products in PE bags were storage for 1 month at ambient temperature. The phenolic and flavonoid compounds, color, texture of the dried samples were determined compared with control products. The sensory acceptance of vegetable snacks (dried vegetables with seasoning spices) was evaluated by using 9-point Hedonic scale. The results showed that, OD was affected antioxidant content of the products ($p<0.05$), depended on type of vegetables. The flavonoids, higher than 50% was remained in osmotically dried pumpkin as compared to a control one, but the advantage on phenolics retention was not found. Total color change of the snacks was decreased by OD. However, sensory characteristics and hardness value was not improved by OD. The process optimization concerning on solution types, soaking and drying conditions will be investigated in further work in order to promote sensory acceptability. The above results suggest that the OD process used in this work could be recommended as a simple method for healthy products, flavonoid rich products. In addition, this simple process may provide beneficial health effect to the consumers economically.

Keywords: antioxidant, drying, flavonoids, functional food, pretreatment

Introduction

Dehydration of fruits and vegetables is a process commonly used to preserve the product. However, collapse of the structure, discoloration and beneficial compound loss are frequent quality problem. Most vegetables are generally dried convectively with 50-80°C drying temperature. Nowadays, consumer requirement is more product quality, providing health benefit. Mushroom and vegetables, important source of dietary fiber, mineral and vitamin, are rich in various polyphenolic compounds recognized as an efficient antioxidant. However, impact of hot air drying on degradation of certain components has been widely reviewed, while drying using an advantage technique such as vacuum drying, freeze drying and microwave drying is still not widely used for commercial purpose due to both technique and cost factor. The combination of osmotic dehydration (OD) and hot air drying is widely used process that could improve the qualities of dried fruit and vegetable products. OD, immersing food samples in osmotic solutions (sucrose, glucose, corn syrup, maltose, sorbitol, etc.) is a viable process for the partial removal of water from cellular foods without a phase change. The water from the food flows towards the solution

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and, in an inverse sense, the solids from the solution to the product. The type of osmotic agents always plays an important role in the osmotic dehydration affecting the mass transfer of water and solids (Tregunno and Goff, 1996; Panagiotou et al., 1999) and product characteristics (Nieto et al., 2004; Moreira et al., 2011; Chottanom and Srisa-ard, 2011). OD in salt (Torringa et al., 2001; Singla et al., 2011) and sucrose (Chottanom and Phoungchandang, 2005; Chottamom et al., 2012) solutions as a pretreatment for improvement of dried fruit and vegetable properties has been reported. OD in salt solution has traditionally been used in food processing, like drying and picking vegetables, brining of chesses, curing meat, etc. The low water activity of salt solution promotes driving force of mass transfer which depends upon concentration, food: solution ratio, temperature, contact time, pressure, food structure and feature, etc. Advantage of salt solution for dried foods includes flavor enhancing, decreasing of drying time and water activity, and increasing of thermal conductivity property, porosity and rehydration capacity. There were numerous results of physical improvement by OD (Torringa et al., 2001; Mayor et al., 2006; Chenlo et al., 2006) but an advantage on antioxidant property of dried vegetables is still not concluded significantly. The objective of this work was to study the effect of osmotic dehydration using salt solution as a pretreatment on certain properties of pumpkin, sweet potato and mushroom snacks, focusing on color, texture, phenolic and flavonoid compound stability. In addition, effect on sensory acceptance was also determined.

Materials and Methods

Preparation of vegetables

Raw materials for the preparation of vegetable snacks such as pumpkin, sweet potato and Sarjor-caju mushroom were purchased from the agricultural super market of Mahasarakham province. Each vegetable with the same size, weight and color were selected. All vegetables were stored at 4^{o}C until applying to further processing (not longer than 72 h). The peeled pumpkin was cut into 20x50x2 mm and the peeled sweet potato was cut into round pieces with 2 mm thickness and 50 mm diameter. The Sarjor-caju mushroom was cut into round pieces with 30 mm diameter.

OD solution was 5% sodium chloride (NaCl). Each vegetable sample was soaked in 1.5% calcium chloride solution and then blanched in boil water with 2.5% citric acid for 1 min. After cooling, the samples were soaked in the OD solution for 0, 30 and 60 mins. and then drained before subjecting to a drying step.

Air drying

The vegetable pieces, either unsoaked or soaked samples were dried in a hot air oven at 60^{o}C until their a_w value were 0.35-0.45 to obtain crispiness texture of the products. Drying air temperature was monitored by using a thermocouple connected to a data logger with an accuracy of $\pm$1^{o}C. The obtained dried-products were storage for 1 month at ambient temperature in polyethylene bags.

Color and texture characteristics

Color measurement was performed by using a Minolta color meter (CR-300, Japan). The coordinates of the color CIE-$L^*a^*b^*$ of the sample surface were obtained by reflection. L^*, a^* and b^* represent the lightness, redness, and yellowness values, respectively. The total color change (ΔE^*) was calculated as followed:

$$\Delta E^* = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$$

where ΔL, Δa, Δb aer the changes in each individual color parameter.

Texture measurement was performed by using a TA.XT2i texture analyzer (Stable Micro System, UK) to determine puncture force passed through the samples. The cylinder probe of 2 mm diameter was used. The test speed was 1 mm/s. The distance between two brackets was 2.7 cm (for pumpkin and sweet potato measurement). The Sarjor-caju mushroom was placed on a stainless steel plate with hole for the penetration test because of size limitation. Eight samples were used in each treatment. The force values of the first peak and the highest peak of penetration were recorded as facturability and hardness values, respectively. Each result was an average of four replicate measurements.

Flavonoid and phenolic contents

Flavonoid content, expressed as mg catechin equivalents/ g samples was determined at 510 nm by using colorimetric method by Peinado et al. (2009) with some modifications. The Folin-Ciocalteu method slightly modified from Bae and Suh (2007) was used to determine phenolic content at 750 nm and the result was expressed as mg gallic acid equivalents/g sample.

Sensory characteristics

The sensory acceptance of vegetable snacks with seasoning spice powder (mixture of pepper, paprika, garlic) was evaluated by using 9-point Hedonic scale (dislike extremely – like extremely). The evaluated parameters, appearance, color, flavor, texture and overall acceptability were obtained from 30 panelists.

Results and Discussions

Soaking in salt solution is generally known as the preparation of vegetables prior drying process. NaCl is the preferred osmotic agent for vegetables because it provides partial water removal from fresh materials, decreasing drying time, decreasing of water activity and enhancing of flavor and texture as well. OD treatment of foods effecting physical-chemical properties of fruits and vegetables has been viewed upon as an important process condition. The optimum OD may enhance stability of dried product as clearly shown in the color stability of mushroom and pumpkin samples (**Table 1**). The total color change of dried mushroom was clearly decreased around 39% and 20% by OD pretreatment for mushroom and pumpkin samples, respectively. Color change in dried vegetables from a convective drying normally caused by Maillard reaction (non-enzymatic browning) which exhibits a maximum rate at intermediated a_w of the foods. The Maillard reaction creates brown pigments in certain

Table 1 Total color change (ΔE^*) of vegetables snacks

OD time (min)	Pumpkin	Sweet potato	Mushroom
0	47.75 ± 1.17^{c}	18.00 ± 3.70^{b}	18.79 ± 5.45^{c}
30	40.05 ± 3.50^{ab}	14.93 ± 1.92^{a}	12.49 ± 4.23^{ab}
60	38.18 ± 0.79^{a}	17.07 ± 0.66^{b}	11.50 ± 0.20^{a}

a,b… The different letters in the same colum indicates to difference of the average values (p<0.05)

cooked foods by rearranging amino acids and certain sugars (reducing sugars), which then arrange themselves in rings and collections of rings that reflect light in such a way as to give the products a brown color.

Generally, drying temperature (40-80°C) speeds up the Maillard reaction because heat both increases the rate of chemical reactions and accelerates the evaporation of water. As the food dries (a_w lower than 0.7), the concentration of reactant compounds increases and the temperature climbs more rapidly. NaCl molecules can play an important role in a_w depression during air drying and storage as well. The rapid rate of a_w depression (< 0.6 aw), the high stability of the product, especially at intermediate to low a_w range. Therefore, Maillard reactions was retarded during drying of food materials and storage by a proper OD pretreatment(Chottanom and Phoung-chandang, 2005; Krokida and Maroulis, 2000; Mandala et al., 2005). In our work, the products were kept for 1 month at ambient temperature because color change caused by OD of the initial dried products (day 0) was unclear. The variation of color parameters was observed which was similar to the un-clear tendency of lightness parameter (L^*) of apples dried by convectional, vacuum, microwave, freeze drying and osmotic dehydration reported by Krokida and Maroulis (2000). Therefore, existence of thermodynamic equilibrium is required in color monitoring of dried vegetables.

Table 2 Fracturability (g) and hardness (g) values of vegetables snacks (a_w 0.35-0. 45)

OD time (min)	Pumpkin		Sweet potato		Mushroom	
	Fracturability	Hardness	Fracturability	Hardness	Fracturability	Hardness
0	138.33±9.39	231.73±17.29	229.97±114.36	934.50±62.31	408.67 ± 54.65^{b}	539.67 ± 46.53^{b}
30	194.73±74.40	274.63±49.77	260.00±26.90	977.57±110.87	395.93 ± 37.97^{ab}	462.57 ± 70.00^{a}
60	162.33±30.95	231.20±27.67	206.27±61.90	974.90±108.33	333.40 ± 72.50^{a}	487.60 ± 62.89^{ab}

a,b… The different letters in the same column indicates to difference of the average values (p<0.05).

Table 2 shows texture parameters, including fracturability, and hardness of dried vegetables. The force values of the first peak recorded as fracturability value could indicate crispiness of snacks. Drying of vegetables with hot air usually results in considerable shrinkage and formation of dense structure. Using salt solution did not significantly improve texture property of pumpkin and sweet potato snacks. Possibly, the significant effect of OD condition on moisture reduction (~4%) of initial moisture content and drying time reduction (~20 min) could not be observed. All thin-piece vegetables (pumpkin and sweet potato) were blanched in the preparation step resulting to open pore structure of the sample tissue. Therefore, effect of OD using low medium concentration might be hidden. On the other hand, OD pretreatment of the mushroom sample provided texture improvement of mushroom. The hardness of dried mushroom was reduced, while crispiness of the sample was increased, which was confirmed by the fracturabilty force was decrease. Solution concentration, soaking time, material properties and drying methods usually results in considerable properties of dried products. Salt solution used in this work was quite low as compared to another report, because of sensory property concerning. Combination effect of blanching and OD in increasing of intercellular space was observed when the cell interspaces at the corner of the cell increased by blanching. After OD, solute accumulation occurs, the tissue maintain its original arrangement of cells.

Table 3 Flavonoid content (mg catechin equivalents/ 100g samples) of vegetables snacks

OD time (min)	Pumpkin	Sweet potato	Mushroom
0	29.39±0.93	24.64±0.31	25.10±0.50
30	45.91±2.79	22.30±1.04	28.67±0.91
60	45.69±2.00	20.39±0.20	27.95±0.52

a,b… The different letters in the same colum indicates to difference of the average values ($p<0.05$)

resulted to a higher open-pore. However, blanching condition for food material containing more starch should be optimized. In this present work, all vegetables were completely blanched. Pumpkin, potato and mushroom are rich in carbohydrates. Mentioning, carbohydrates in pumpkin and potato are in the form of starch but for mushrooms are in the form of glycogen, chitin and hemicelluloses instead of starch. Concerning the blanching effect, heat will promote open pore of mushroom tissue, while lead to gelatinization of starch matrix and then limit the pore structure. Therefore, the OD process using low salt concentration was interesting for texture development in drying of blanched mushroom as compared with pumpkin and potato samples. The use of higher salt concentration effect on product structure has been reported, confirming the porosity occurred by OD pretreatment in salt solution. Torringa et al. (2001) reported an effectiveness of salt solution, 10 and 15% w/w on improvement of rehydration property, shrinkage and porosity of mushroom dried by using a microwave-hot-air tunnel oven.

Table 4 Phenolic content (mg gallic acid equivalents/ 100g samples) of vegetables snacks

OD time (min)	Pumpkin	Sweet potato	Mushroom
0	161.09±3.81	125.06±0.31	231.91±5.28
30	162.15±10.64	94.33±1.04	162.38±2.69
60	152.15±8.04	88.47±0.20	150.01±2.88

a,b… The different letters in the same colum indicates to difference of the average values ($p<0.05$)

Table 3 and **Table 4** show flavonoids and Phenolic contents of vegetables snacks, respectively. The result obtained in the present study indicated that OD could promote stability of flavonoids as compared to phenolics. The flavonoids content in OD pumpkin snack was 1.5-fold higher than those in untreated snack. The protective mechanism by OD on flavonoids stability needs to be further investigated. Increasing of antioxidant compounds has been reported, because of extract ability of some compounds after processing (Choi et al., 2006; Patras et al., 2009). On the other hand, OD for 60 mins. seems to induce loss of phenolics. Concerning the cell plasmolysis and semipermeability damage by osmotic pressure (Spiess, 2002), high concentrate medium or long process time significantly induced solubility of soluble substances into osmotic solution as found in numerous reports (Chottanom and Srisa-ard, 2011; Chottamom et al., 2012; Torreggiani and Bertolo, 2002). Phenoic compounds are generally thermal-labile and destroyed during the process and storage. However, there was a report of phenolic preservation by OD of mushroom (*Agaricus bisporus*) snack dried at 45°C for two and a half hours (Singla et al., 2011), possibly due to the lower drying temperature. Besides plant properties, factors influencing antioxidant stability include temperature, oxygen, light, enzyme, metal, solubility, etc. Generally, phenolic acids are usually water soluble substance, especially salvianolic acid B (Huang et al., 2010). In addition, phenoic acid is also thermal-labile and easily destroyed during the process. Even though phenolic acid and flavonoids are major classes of phenolic compounds in dietary fiber plants, phenolic compounds include simple phenols, tannins, stilbenes, curcuminoids, coumarins, lignans, quinones, and others as well. Enzymatic reaction plays an important role in reducing in some phenolics, focusing in the thermal processes using low-moderate heat. A moderately heat-stable enzyme polyphenol oxidase (PPO) may be stimulated and bring about transformation of phenol compounds. PPO led to significant change in the phenolic compounds of guava leaves dried at 50°C (Nantitanon et al., 2010) and activation of PPO in litchi pericarp by the moderate heat has been reported (25). Flavonoids are some of the most common phenolics, commonly have the basic skeleton of phenylbenzopyrone struc-ture (C 6 -C 3 -C 6) consisting of 2 aromatic rings linked by 3 carbons, and often responsible alongside the carotenoids and chlorophylls for their blue, purple, yellow, orange and red colors. The different chemical structures and bonding with other compounds related to the antioxidant stability during soaking in OD medium and/or hot air drying should be considered to explain the evidence.

Table 5 Sensory score from 9-point Hedonic scale of vegetables snacks

OD time (min)	Appearance	Color	Flavor	Texture	Overall acceptability
Pumpkin					
0	5.53±0.99[a]	4.8±1.01[a]	3.33±1.18[a]	3.67±1.68[a]	3.73±1.49[a]
30	6.13±1.25[a]	5.93±1.28[b]	4.53±2.07[b]	4.67±1.45[b]	4.73±1.87[b]
60	5.73±1.22[a]	5.93±1.39[b]	4.33±1.18[b]	4.33±1.50[b]	4.47±1.87[b]
Sweet potato					
0	4.73±1.39[a]	4.8±1.37[a]	3.13±1.19[a]	4.53±1.96	4.07±1.58[a]
30	4.87±1.41[a]	5.07±1.33[a]	4.73±1.75[c]	4.73±2.05	5.00±1.73[c]
60	4.67±1.23[a]	5.93±1.62[a]	4.00±1.65[b]	4.4±1.99	4.60±1.72[b]
Mushroom					
0	6.47±1.30[a]	5.87±0.83[a]	4.27±1.22[a]	3.93±1.39[a]	4.93±1.16[a]
30	6.33±0.90[a]	6.13±0.74[a]	5.07±1.22[b]	4.27±1.67[b]	5.27±1.28[b]
60	6.2±0.86[a]	6.33±1.05[a]	4.8±1.08[b]	4.6±1.40[b]	4.73±1.16[a]

a,b… The different letters in the same colum for each snack indicates to difference of the average values ($p<0.05$)

Non enzyme process occurring in drying process and storage might lead to change of antioxidant composition (Capecka et al., 2005). However, the total flavonoids levels decreased marginally in mushrooms *(Agaricus bisporous)* snack obtained from OD process using a short contact- time have been reported (Singla et al., 2011; Singla et al., 2009). Therefore, preservative role of OD agents on antioxidant stability relates to concentration of solid and liquid in plant tissue matrix.

OD pre-treatment seams to increase snack acceptability but sensory scores were satisfied inadequately (**Table 5**). The sensory scores of all snacks were in the range of 3-6, indicating dislike moderately – like slightly. Flavor and texture attributes are challenged in product development. The process optimization concerning on solution types, soaking and drying conditions will be investigated in further work in order to promote sensory acceptability.

Conclusion

Using OD with a proper soaking time brings about good quality of dried vegetables or snacks. The above results suggest that OD pumpkin snack may serve as a good snack, because of high content of flavonoids. Texture of mushroom snack was improved by OD pre-treatment. The knowledge gained from this work is expected to be economically beneficial for producing healthy snacks to the consumers. The process optimization concerning on OD solutions, pre-treatments and drying methods will be investigated in further work to improve sensory characteristics of the vegetable snacks.

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