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Synergistic effect of osmotic dehydration and vacuum drying in strawberry (*Fragaria*) jam production

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Strawberry is deep red in color with specific shape and flavor. It is a good source of vital vitamins minerals, natural antioxidants with diverse phytochemical constituents. However it’s highly perishable during postharvest owing to its highly fragile structure and its high respiration rate. It is highly susceptible to bruises and fungal attacks which affect bioactive components, antioxidant activity, market potential and consumer access. Osmotic dehydration has got a great attention recently as an innovative approach for storage of fruits and vegetables. The low temperature and fast mass transfer conferred by vacuum combined with osmotic dehydration in advance generates very rapid, low temperature drying and thus it has the potential to improve energy efficiency and product quality. In order to produce one kind of jam prepared from strawberry, Strawberries were osmotically dehydrated prior to vacuum drying. we have focused on different parameters in osmotic dehydration, vacuum drying to the physicochemical, microbial and sensory characteristics in the strawberry jam. Our results revealed that blanching at 100ºC in 15 seconds, osmotic dehydration by 14% sugar addition, vacuum drying at 55ºC under pressure -0.8 bar during 4 hours could produce strawberry jam with the lowest moisture content, the highest vitamin C retention as well as the best overall acceptance. This product could be stored under ambient temperature for 6 months without any presence of yeast or mold. These findings demonstrated that combination of osmotic dehydration and vacuum drying was clearly created a better synergistic effect.

Keywords: Strawberry jam, osmotic dehydration, vacuum drying, physicochemical, microbial, sensory, synergistic

INTRODUCTION

Strawberries (*Fragaria*), a rich source of phytochemicals (ellagic acid, anthocyanins, quercetin, and catechin) and vitamins (ascorbic acid and folic acid), have been highly ranked among dietary sources of polyphenols and antioxidant capacity. Bioactive compounds in strawberry revealed high abundance of anthocyanins, phenolics, flavanols, and cinnamic acid (Nguyen et al., 2019; Sara et al., 2008; Forbes-Hernandez et al., 2016; Giampieri et al., 2012; Giampieri et al., 2014; José Cheel et al., 2005; Häkkinen et al., 2000; Panico et al., 2009). Consumption of strawberries has several other health benefits, such as improved eye condition, enhanced brain function, and relief from high blood pressure, arthritis, and various cardiovascular diseases (Afrin et al., 2016; Elena et al., 2010; Arpita et al., 2014; Alvarez-Suarez et al., 2014; Minh et al., 2019).

Osmotic dehydration is an approach used for the partial removal of moisture from plant tissues by immersion in a hypertonic solution such as sugar or salt to reduce the water activity before full drying step (Pandharipande et al., 2012). The removal of moisture during osmotic process is mainly by diffusion and capillary flow. It presents some benefits such as reducing the damage of heat to the flavor, color, inhibiting the browning of enzymes and decrease the energy costs (Rafiq, 2012). The osmotic agent has a greater impact on texture, which causes changes in the sensory attributes such as gumminess, even crispness and flavor of the product (Ana et al., 2016). Concentration of solution is an important factor in the osmotic dehydration process. Increased osmotic agent concentrations result in the increment of solid gain and water loss. Water loss and soluble solid content increased linearly with the increase of sugar concentration and temperature (Rahman and Lamb, 1990). The use of vacuum drying lowers the solvent boiling temperature, permitting operation at lower temperatures, directly influencing final product quality (Péré and Rodier, 2002). Vacuum-dried materials are characterized by better quality retention of nutrients and volatile aroma (Giri et al., 2014).

Strawberry is a seasonal fruit and is available in abundance during particular season of the year (Haseeba et al., 2018). Strawberries are highly susceptible to mechanical injury, physiological disorders, fungal activity and water loss (Romanazzi et al., 2013). They have a very short post-harvest shelf life, which effects market potential and consumer access (Aday and Caner, 2014). The cultivation and awareness of the numerous benefits of strawberry *(Fragaria)* is springing up in Vietnam and there arise the need to produce value-added products. Objective of this study focused on different parameters in osmotic dehydration, vacuum drying to the physicochemical, microbial and sensory characteristics of the strawberry jam.

MATERIALS AND METHODS

Material

Strawberry fruits were collected from Vinh Long province, Vietnam. Only undamaged healthy fruits were selected. After collecting, they must be conveyed to laboratory within 8 hours for experiments. They were washed under tap water to remove foreign matters. The raw samples were washed and kept at room temperature to drain. Afterwards, the samples were blanched and dried by vacuum drying or conventional drying. After drying, samples were kept at ambient temperature for 2 hours before estimating the physicochemical and sensory characteristic. Jam samples were stored at normal condition for 6 months. In two month-interval, jam samples were counted the yeast and mold to verify the food safety.

Researching procedure

Effect of osmotic dehydration to physicochemical and sensory characteristics of semi-jam

Each sample was cut into two pieces. They were subjected to blanching at 100ºC in 15 seconds. After blanching, these samples were drained and then soaked with sugar in differerent percentage (8%, 10%, 12%, 14%, 16%) for 4 hours to create a partial water removal by osmotic gradient. For each osmotic dehydration treatment, 600 g of fresh sample was used (in triplicate). Moisture content (%), vitamin C (mg/100g), and sensory score were major indicators to determine the appropriate sugar supplementation during osmotic dehydration.

Effect of vacuum drying condition to physicochemical and sensory characteristics of jam

Blanched samples were soaked with 14% sugar for 4 hours in advance. Then they were subjected to vacuum drying with different temperature (40, 45, 50, 55, 60ºC) at different pressures (-0.2, -0.4, -0.6, -0.8, -1.0 bar). Drying time was set in 4 hours. After drying, these samples were put to cool at ambient temperature before analyzing the moisture content (%), vitamin C (mg/100g), and sensory score. For each drying method, 600 g of semi-dehydrated sample was used (in triplicate).

Shelf-life of jam under storage

After drying, dried jams were kept in dedicated bag at ambient temperature for 6 months. In 2 month-interval, jam samples were counted the yeast and mold to verify the food safety. For each storage sample, 100 g of jam was used (in triplicate).

Chemical, sensory and statistical analysis

Moisture content (%) was measured by drying at 105ºC to constant weight and then comparing between the initial and final weight. Vitamin C (mg/100g) was determined by 2-6-dichloroindophenol titration (Chen et al., 2016). Yeast/ mold was counted by Petrifilm-3M.Sensory score was evaluated by a group of panelist using 9 point-Hedonic scale. The experiments were run in triplicate with three different lots of samples. Statistical analysis was performed by the State graphics Centurion XVI

RESULTSAND DISCUSSION

Effect of osmotic dehydration to physicochemical and sensory characteristics of semi-jam

Osmotic dehydration improves the product quality by reducing the damage of heat to the flavor, color, inhibiting the browning of enzymes and decreases the energy costs (Torres et al., 2006). Osmotic dehydration is affected by various parameters such as osmotic agent, solute concentration, temperature, time, size, and shape and tissue compactness, agitation and solution/sample ratio. The osmotic dehydration should be conducted before the drying process to improve the mass transfer rate while maintaining the product quality and wholesomeness (Mina et al., 2013). In our research, strawberry fruits were subjected to blanching at 100°C in 15 seconds. After blanching, these samples were drained and then soaked with sugar in different percentage (8%, 10%, 12%, 14%, 16%) for 4 hours***.*** Our results were clearly presented in table 1, we could see that 14% sugar was adequate to create an osmotic effect to partially remove moisture before the next official drying step. In another research, the osmotic pretreatment did not help in terms of drying time and energy saving but provided a better quality of dried product (Viboon et al., 2008). Water activity in strawberry was lowered and promoted the constituents of flavor and moving of Anthocyanins to osmotic solution by using of this practice (Osorio et al., 2007). The most helpful effect of osmotic dehydration was on lycopene, ascorbic acid and on the color quality (Haseeba et al., 2018).

Effect of vacuum drying to physicochemical and sensory characteristics of jam

Vacuum drying technology is an important process for drying highly heat-sensitive materials. The water evaporation proceeds more rapidly at low pressures (Bazyma and Kutovoy, 2005). In our current research, the semi-osmotic-dehydrated samples were subjected to vacuum drying with different condition: temperature (40, 45, 50, 55, 60°C) at -0.2 bar; pressure (-0.2, -0.4, -0.6, -0.8, -1.0 bar) at 55°C during 4 hours. Our results pointed out that vacuum drying at 55°C under -0.8 bar was adequate for drying of this fruit (see table 2 and table 3).

Table 1: Effect of sugar percentage (%) to the physicochemical and sensory characteristics of jam

Sugar percentage (%)	8	10	12	14	16
Moisture content (%)	75.31±0.03[a]	66.17±0.02[b]	62.48±0.01[c]	57.43±0.01[d]	52.81±0.01[e]
Vitamin C (mg/100g)	21.53±0.01[a]	20.46±0.00[ab]	19.84±0.02[b]	19.36±0.03[bc]	19.05±0.00[c]
Sensory score	4.53±0.02[c]	5.14±0.01[bc]	5.69±0.00[b]	6.72±0.02[a]	6.08±0.00[ab]

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = *5%).*

Table 2: Effect of vacuum drying temperature (40, 45, 50, 55, 60°C) at pressure -0.2 bar to the physicochemical and sensory characteristics of strawberry jam

Vacuum drying temperature (°C)	**40**	**45**	**50**	**55**	**60**
Moisture content (%)	26.83±0.02[a]	25.04±0.02[ab]	23.79±0.01[b]	22.45±0.03[bc]	22.01±0.02[c]
Vitamin C (mg/100g)	16.79±0.00[a]	16.21±0.01[ab]	16.03±0.03[ab]	12.85±0.01[b]	11.07±0.01[c]
Sensory score	7.25±0.01[c]	7.71±0.03[bc]	8.05±0.02[ab]	8.58±0.02[a]	7.95±0.00[b]

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = *5%).*

Table 3: Effect of vacuum drying pressure (-0.2, -0.4, -0.6, -0.8, -1.0 bar) at temperature 55°C to the physicochemical and sensory characteristics of strawberry jam

Vacuum drying pressure (bar)	**-0.2**	**-0.4**	**-0.6**	**-0.8**	**-1.0**
Moisture content (%)	22.45±0.03[a]	21.03±0.02[ab]	20.17±0.03[ab]	19.45±0.01[b]	19.40±0.01[b]
Vitamin C (mg/100g)	12.85±0.01[b]	12.98±0.01[ab]	13.03±0.02[ab]	13.09±0.00[a]	13.10±0.00[a]
Sensory score	8.58±0.02[b]	8.64±0.00[ab]	8.75±0.03[ab]	8.83±0.02[a]	8.83±0.02[a]

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%).

Table 4.Microbial safety of strawberry jam under storage

Storage (months)	0	2	4	6
Yeast/ mold (cfu/g)	Not detected	Not detected	Not detected	Not detected

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%).

Shelf-life of strawberry jam under storage

The major purpose of drying is to remove moisture until the water activity is low enough to prevent proliferation of microorganisms and increase the shelf life of product. In our research, dried jams were kept in dedicated bag at ambient temperature for 6 months. In 2 month-interval, jam samples were counted the yeast and mold to verify the food safety. Our results noted that there was not any appearance of yeast or mold on strawberry jam during 6 months of storage (see table 4). It could be explained the low moisture of jam preventing yeast or mold from proliferation.

CONCLUSION

Vacuum drying is one of the most energy demanding processes. Water evaporation takes place at lower temperatures under vacuum, and hence the product processing temperature can be significantly lower, offering higher product quality. A combination of osmotic dehydration and vacuum drying created a synergistic effect consuming less energy than other drying methods because it can be performed at low temperature while maintaining the product quality and wholesomeness. Moisture content is partly removed by osmotic substance and further dehydration in a vacuum dryer is fully reduced to a stable level. Strawberry is very popular due to its attractive fruits with unique taste, spectacular aroma, and smooth red texture. Strawberry contains high levels of micronutrients and phytochemical compounds We have successfully verified various major variables influencing to the quality of the strawberry jam. From this finding, consumers have more chance to utilize one kind of processed product from this valuable fruit.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Minh Phuoc Nguyen arranged the experiments and also wrote the manuscript.

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