



Osmotic dehydration kinetics of oyster mushroom

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Abstract

This research was carried out to study the effect of osmotic dehydration behavior of oyster mushroom. The effect of solution concentration, immersion time and temperature on mass transfer parameters were observed during osmotic dehydration of oyster mushroom at three different temperatures -12 , 27 and 45°C . A number of process parameters on osmotic dehydration such as water loss (WL), solid gain (SG), and normalized solid content (NSC) were investigated. Results showed that increase in salt concentration and immersion time resulted in %WL, %SG and NSC. The highest NSC (4.09 g solids/100g of initial weight of sample) was achieved for product osmosed in 25% salt solution for 6 hr immersion time. The pseudo diffusion coefficient, k was determined by using Fick's First Law of diffusion equation. Plotting k values against inverse absolute temperature an Arrhenius type relationship was developed from which the calculated activation energy values of 1.8 and 3.64 kcal/gm-mole were obtained for 20% and 15% salt solution respectively.

Introduction

A special group of macroscopic fungi, known as mushrooms lack in chlorophyll and hence require a substrate for their own absorptive nutrition. Enzymes producing fungi degrade complex organic matter and absorb the soluble substances (Chang and Miles, 1989). Mushroom is a soft delicate white fruit-body of the fleshy fungi. The microscopic fine thread-like body called mycelium is the real fungus which grows on the substratum or under the surface of soil. When matured, the mycelia come together in a very compact form and sprout and spread as umbrella like structure (Chung *et al.*, 1981). Mushrooms have been evaluated as sources of dietary nutrients and pharmacologically vital compounds beneficial for medicine since times immemorial. They are considered to be a source of many different nutraceuticals such as unsaturated fatty acids, phenolic compounds, tocopherols, ascorbic acid and carotenoids. Thus, they are used directly in diet to promote health, taking advantage of the additive and synergistic effects of all the bioactive compounds present (Pereira *et al.*, 2012; Vaz *et al.*, 2010).

Mushrooms of *Pleurotus* sp. are commonly called 'Oyster mushrooms'. They are the second most popular mushrooms after button mushroom throughout the world (Adejoye *et al.*, 2006) and the most popular in Bangladesh. The production of four species of oyster mushroom: *Pleurotus ostreatus*, *P. florida*, *P. sajor-caju* and *P. high king* cultivated in every season (January to December) in Bangladesh (Uddin M. N. *et al.*, 2011). Nowadays mushrooms are becoming a popular food in daily meal because of their nutritious and medicinal values. Edible mushrooms are rich in protein,

and are excellent source of fibers, vitamins and minerals (Manjunathan *et al.*, 2011). In general, the fruiting bodies of mushrooms contain about 56.8% carbohydrate, 25.0% protein, 5.7% fat and 12.5% ash on a dry weight basis (Ouzouni *et al.*, 2009).

Edible mushroom in fresh, cooked or processed forms are nutritionally sound, tasteful food source for most people and can be a significant dietary component for vegetarians. The nutritional value of edible mushrooms compares favorably to that of most vegetables.

Fruits and vegetables are perishable due to their high moisture content. Osmotic dehydration (OD) as a pre-drying treatment has received considerable attention in recent years, as it reduces energy consumption, improves food quality, and reduces the drying time. The technique consists of immersing fruit/vegetables in a hypertonic solution to concentrate vegetables or fruits. Sereno *et al.* (2001) stated that osmotic dehydration is a useful technique that involves product immersion in a hypertonic aqueous solution leading to loss of water through the cell membranes of the product and subsequent flow along the inter-cellular space before diffusing into the solution.

The osmotic process is a method of partial removal of water from product by immersing it in a hypertonic solution. The process is facilitated by the osmotic pressure difference between the food material (hypotonic medium) and concentrated osmotic solution (hypertonic medium). As osmotic dehydration does not give a product of low moisture content considered for shelf stable therefore osmosed products are needed

further dried up to desired moisture content, in association with other methods of food preservation including freezing, vacuum dehydration and oven or freeze drying (Torrington *et al.*, 2001). Osmotic dehydration makes significant changes in the final dehydrated product such as volume reduction, membrane alteration and membrane separation from the cell wall. It also increases nutritional, sensorial and functional properties of food without changing its integrity (Torrengiani, 1993).

Osmotic dehydration is a process through which water is removed from the cell membrane and solid uptake. Time, temperature, solution concentration and also other parameters has a notable effect on osmosis. Therefore, current research was designed with the following objectives:

- i) To determine the osmotic drying behavior of oyster mushroom.
- ii) To assess the effect of different parameter (time, temperature, solution concentration etc) on osmosed mushroom.
- iii) To investigate the mass transfer actions of osmosed mushroom.

Materials and Methods

The experiment was conducted in the laboratory of the Department of Food Technology and Rural Industries, Faculty of Agricultural Engineering and Technology, Bangladesh Agricultural University, Mymensingh during October 2012- April, 2013.

Sample preparation

Fresh oyster mushrooms were collected from Horticulture Centre, Keawatkhali, Mymensingh. Five different salt concentrations (i.e. 5%, 10%, 15%, 20% and 25%) were made using salt and distilled water. Salt was used for retarding oxidative non-enzymatic browning (Kumar *et al.*, 2009).

Other materials such as drying tray, polythene bags and distilled water were provided by the laboratory of the Department of Food Technology and Rural Industries.

Osmotic dehydration treatment

Fresh mushroom were collected and initial moisture content was determined by oven drying method (AOAC 2005). Approximately 100gm of mushrooms were immersed into 5%, 10%, 15%, 20% and 25% salt

solution using a solution to product ratio of 6:1 at different temperatures (12, 27 and 45°C) for 30 min, 1hr, 2hr, 3 hr, 4hr and upto 6hr. At the end of each definite time interval samples were removed and boltted gently with tissue-paper. The osmosed mushroom was then weighted and moisture content of each individual sample was determined. Percentage of water loss (%WL), solid gain (%SG), total solid (TS), and normalised solid content (NSC) were determined according to Hawkes and Flink (1978) with the following equations:

Water loss % WL (wb) =

$$\frac{WWO - (TW - WS)}{WSO + WWO} \times 100, \text{ g solids/100g initial wt. of sample}$$

Solid Gain % SG (wb) =

$$\frac{WS - WSO}{WSO + WWO} \times 100, \frac{\text{g solids}}{100\text{g}} \text{ initial wt. of sample}$$

$$\text{Total solid, \%TS} = \frac{WS}{TW} \times 100, \frac{\text{g solids}}{100\text{g}} \text{ of initial weight of sample}$$

$$\text{Normalized Solid Content} = \frac{\text{Total solids at any time}}{\text{Initial solids content}}$$

Where, TW = total weight of the sample upon removal from the osmosis solution, WS = total weight of solid content of the sample determined after removal from the osmosis solution, WSO = solid content of the initial sample, WWO = water content of the initial sample.

Statistical Analysis

The experimental data were evaluated by analysis of variance (ANOVA) and means were compared at a significance level of 5%, by using Statistical Package for Social Science (SPSS 16th version).

Results and Discussion

Effect of solution concentration and temperature on normalized solid content (NSC)

Solution concentration has a more noticeable effect on Normalised Solid Content (NSC). For the investigation of the effect of solution concentration on NSC, experiments were conducted with 5%, 10%, 15%, 20% and 25% salt solution for a period of 6 hrs.

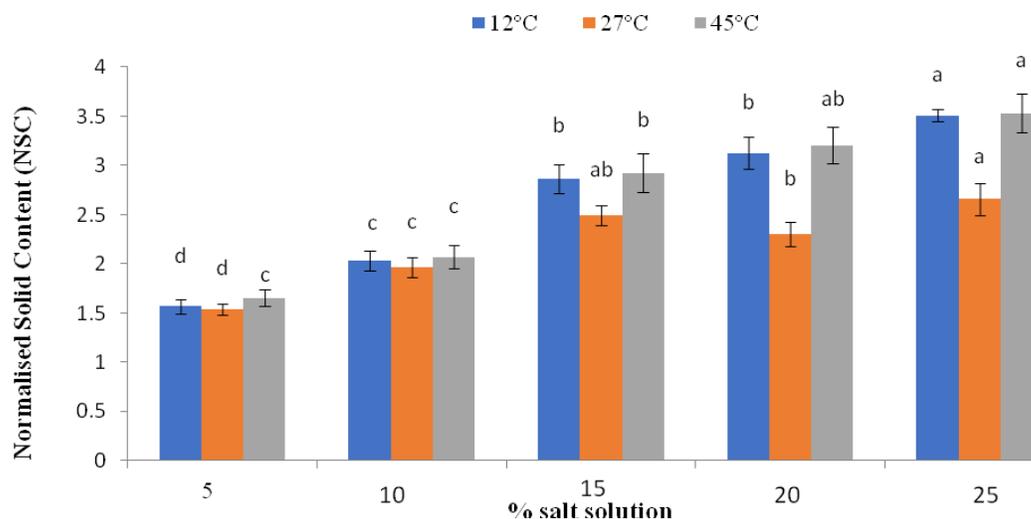


Fig. 1. Effect of solution concentration on NSC of osmosed mushroom at three different temperature (12, 27, 45°C) with error bar representing standard error of mean at 95% confidence level. [*^{a-d} means followed by different subscript alphabets in each temperature are significantly different ($p < 0.05$) among different normalised solid content]

From the above Fig. 1 it is seen that at a given time increase in salt concentration gave increased NSC. In 5% and 10% salt solution NSC content are statistically different from 15% to 25% salt solution because no overlap is occurred among the error bar.

Mushroom osmosed in 25% salt solution for 6 hr give significantly higher NSC than the other sample osmosed at 20%, 15%, 10% and 5% at ($P < 0.05$). Mushroom osmosed in 25% salt solution for 6 hr provides significantly higher NSC (3.53) at 45°C followed by NSC 3.51 at 12°C and 2.66 NSC at 27°C, while at 5% salt solution significantly lower NSC (1.54) was found at 27°C followed by 1.65 NSC at 45°C and 1.57 NSC at 12°C.

Hawkes and Flink 1978, Islam 1980 observed that, the higher NSC with increased solution concentration at a given immersion of time is due to higher activity gradient. The increased NSC at a given solution concentration and time with increased solution temperature up-to 27°C is due the fact that NSC is related to \sqrt{t} by pseudo diffusion coefficient (Hawkes and Flink, 1978) which is related to temperature by and Arrhenius type equation (Singh and Heldmen, 2008).

Effect of solution concentration and immersion time on percent water loss and percent solid gain

To determine the effects of osmosis solution concentration and immersion time five different salt solution (5, 10, 15, 20 and 25%) were used as osmosis solution in which samples were immersed for different period of time up-to 6 hrs. and percent water loss (%WL) and percent solid gain (%SG) were determined. Osmosis solution temperatures were maintained at 12°C, 27°C and 45°C. The results are shown in Table 1 and Table 2.

From Table 1 and 2, it is observe that, water loss (%) and solid gain (%) are significantly different at different

immersion time as well as in most of the cases they are also significantly different from each other at a same time in changed temperature. At the same time, water loss (%) and solid gain (%) are significantly different at different solution concentration also at constant concentration in different temperature (Table-2).

In general the results show that, as time of immersion increases water loss (%WL) increases for a given solution concentration and so is solid gain (% SG) but the water loss (%WL) is always significantly higher than solid gain (%SG). Similarly, for constant immersion time (6 hr) water loss (%) rises with increasing concentration of salt in solution up to 25% salt (48.33 %WL at 45°C and 42.75 % WL at 27°C) and thereafter at 20% salt solution slightly decrease in %WL is observed (37.13% at 27°C and 45.53 at 45°C).

It is also seen that at constant immersion time (6 hr), solid gain is increases with increasing osmosis solution concentration and 25% salt solution gives high %SG such as 13.02 % SG at 27°C, while at 45°C % SG is as 10.79. The results also show that in general, for constant solution concentration and time as temperature is increased %WL and %SG increased with an exception in each case.

The observed behaviour of immersion time on % WL and % SG has been previously reported by Islam and Flink (1982) and Hawkes and Flink (1978). Iqbal and Islam (2005) while studying osmotic concentration behavior of cauliflower and cucumber in 5 to 15% salt solution observed that at constant solution concentration, increased time gives increased %WL and %SG.

Finally it is observed that 20 and 25% salt solution was more effective than other solutions at the same immersion time.

Table 1. Effect of immersion time on water loss (%) and solid gain (%) of osmosed mushroom

| Immersion time (hr.) | 12 °C temperature | | 27 °C temperature | | 45 °C temperature | |
|----------------------|---------------------------|------------------------|--------------------------|-------------------------|----------------------------|-------------------------|
| | Water loss (%) | Solid gain (%) | Water loss (%) | Solid gain (%) | Water loss (%) | Solid gain (%) |
| 0.5 | 25.16±14.46 ^b | 7.03±3.64 ^a | 22.21±8.37 ^d | 5.30±3.13 ^b | 29.25±10.68 ^d | 4.84±3.04 ^b |
| 1 | 32.26±14.65 ^{ab} | 7.33±3.72 ^a | 25.96±7.42 ^{cd} | 6.08±3.25 ^b | 33.31±9.11 ^{cd} | 5.82±3.02 ^{ab} |
| 2 | 33.76±11.59 ^{ab} | 8.54±4.70 ^a | 31.16±8.85 ^{bc} | 6.59±3.15 ^{ab} | 36.67±7.89 ^{bcd} | 6.54±3.01 ^{ab} |
| 3 | 37.65±11.01 ^a | 9.02±4.62 ^a | 34.75±9.02 ^{ab} | 7.31±3.06 ^{ab} | 42.63±11.65 ^{abc} | 7.24±3.23 ^{ab} |
| 4 | 39.30±10.29 ^a | 9.20±4.93 ^a | 37.13±9.32 ^{ab} | 7.89±3.11 ^{ab} | 45.53±12.26 ^{ab} | 7.92±3.24 ^{ab} |
| 6 | 40.78±10.10 ^a | 9.57±4.96 ^a | 42.75±9.24 ^a | 9.96±5.50 ^a | 48.33±12.25 ^a | 8.88±3.25 ^a |

*^{a-d} Means followed by different subscript alphabets in each column are significantly different (P<0.05) among different immersion time.

* Mean ± standard deviation

Table 2. Effect of solution concentration on water loss (%) and solid gain (%) of osmosed mushroom

| Concentration (%) | 12 °C temperature | | 27 °C temperature | | 45 °C temperature | |
|-------------------|-------------------------|-------------------------|-------------------------|-------------------------|--------------------------|-------------------------|
| | Water loss (%) | Solid gain (%) | Water loss (%) | Solid gain (%) | Water loss (%) | Solid gain (%) |
| 5 | 22.70±4.55 ^b | 2.72±.99 ^e | 21.63±5.13 ^c | 3.61±.90 ^d | 23.01±5.81 ^c | 3.71±1.07 ^d |
| 10 | 27.25±9.47 ^b | 6.15±.68 ^d | 26.29±7.90 ^c | 5.70±2.04 ^c | 35.28±8.29 ^b | 4.04±1.55 ^d |
| 15 | 27.61±7.05 ^b | 14.80±2.86 ^a | 43.44±5.87 ^a | 5.78±2.11 ^c | 42.28±9.21 ^a | 6.62±2.75 ^c |
| 20 | 46.36±5.27 ^a | 7.79±.68 ^c | 35.97±9.48 ^b | 7.82±.98 ^b | 47.62±10.07 ^a | 9.21±1.36 ^b |
| 25 | 50.16±2.54 ^a | 10.78±.83 ^b | 34.30±9.95 ^b | 13.02±3.29 ^a | 48.25±7.09 ^a | 10.79±1.56 ^a |

*^{a-e} Means followed by different subscript alphabets in each column are significantly different (P<0.05) among different solution concentration.

* Mean ± standard deviation

Effect of temperature on percent water loss and percent solid gain of osmosed mushroom

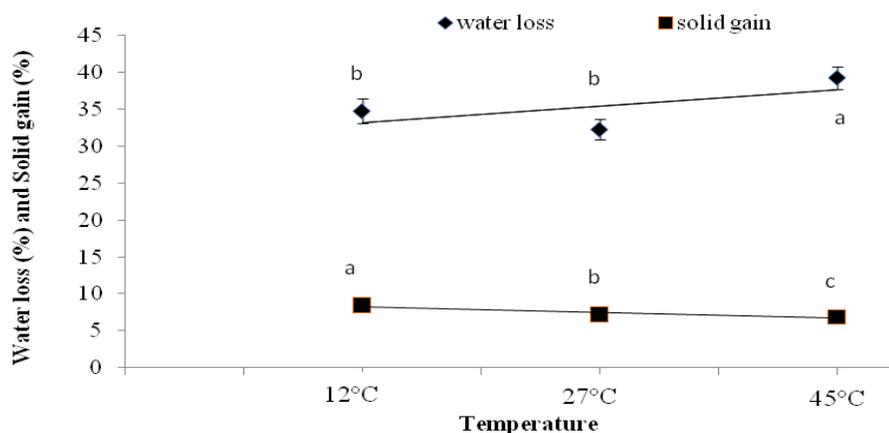


Fig. 2. Effect of temperature on water loss (%) and solid gain (%) of osmosed mushroom with error bar representing standard error of mean at 95% confidence interval.

From the examination of Fig. 2 it is reveals that increasing temperature gave increasing water loss (%) but solid gain decrease with increasing temperature. During osmotic treatment, when temperature increased then water loss and solid gain took place (Alakali *et al.*, 2006, Rafiq Khan, 2012). Beristain *et al.* (1990) stated that increase in temperature of osmotic solution results in increases in water loss, whereas solid gain is less affected by temperature (Tortoe, 2010).

Rahman and Lamb (1990) also observed that at high temperature solute does not diffuse as easily as water through the cell membrane and thus the approach to osmotic equilibrium is achieved primarily by flow of water from the cell resulting in a lower solute gain by the food material.

Kinetics of osmotic dehydration

The most important variable affecting the kinetics of mass transfer during osmotic dehydration is temperature

(Tortoe, 2010). At constant salt solution concentration, increase in immersion time gave increased normalized solid content. In order to analyze osmotic dehydration kinetics as per Fick's First Law (Hawkes and Flink, 1978) equation NSC values for 15% and 20%, of salt solution were plotted vs square root of time (\sqrt{t}) (representative figure 3) for mushroom and a linear relationship is obtained as:

For 15% salt solution
 NSC=0.657 \sqrt{t} +1.767.....at 12°C
 NSC=0.634 \sqrt{t} +1.514.....at 27°C
 NSC=1.242 \sqrt{t} +1.002.....at 45°C
 For 20% salt solution
 NSC=0.352 \sqrt{t} +2.392.....at 12°C
 NSC=0.5 \sqrt{t} +1.610.....at 27°C
 NSC=0.489 \sqrt{t} +1.978.....at 45°C

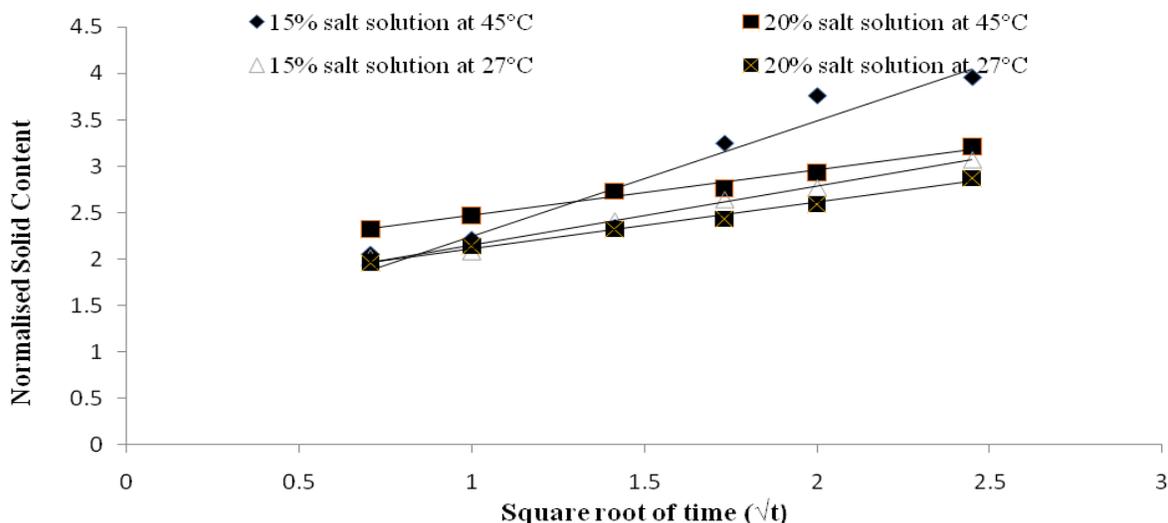


Fig. 3. Effect of square root of time on NSC for 15% and 20% salt solution at different temperature

From the above regression equations and representative Fig. 3 it was seen that the mass transfer co-efficient (k-value) at 15% salt solution for 6 hr osmosis were 0.657, 0.634, and 1.242 at 12, 27 and 45°C, respectively and observed that k value is quite higher at 45°C. Again for 20% salt solution the corresponding k values are 0.352, 0.5, and 0.489, respectively and slightly lower k-value is found for 45°C compared to 27°C. The fluctuating mass transfer coefficient, k value for osmotic dehydration of oyster mushroom may be due to its sensitiveness to temperature which might have destroyed the effectiveness of cellular membrane. Islam (1980) and Pader and Richberg (1968) also showed that high temperature had adverse effect on osmotic dehydration.

Relationship between mass transfer coefficient (k-value) and inverse absolute temperature is generally described by Arrhenius type relationship reported as by Brooker *et al.* (1974) and Singh and Heldmen (2008). The determined k-value for osmosed mushroom was plotted against inverse absolute temperature on semi-log coordinate (figures 4a and 4b) to describe the influence of temperature on osmotic concentration behavior. By regression analysis the following equations were developed:

$$K = 8.93e^{-904/T_{abs}} \quad \text{for 15\% salt solution}$$

$$K = 354.3e^{-1831/T_{abs}} \quad \text{for 20\% salt solution}$$

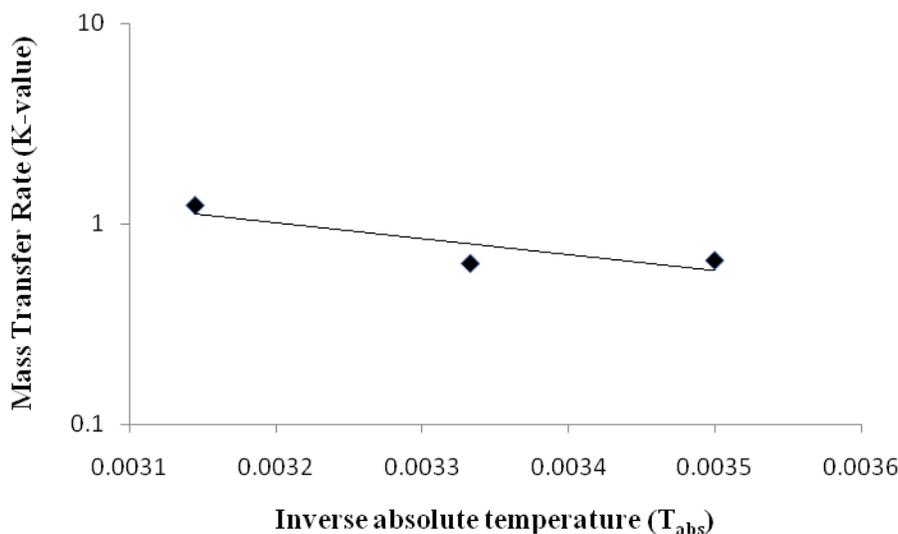


Fig. 4(a). Effect of temperature on mass transfer rate of mushroom at 15% salt solution

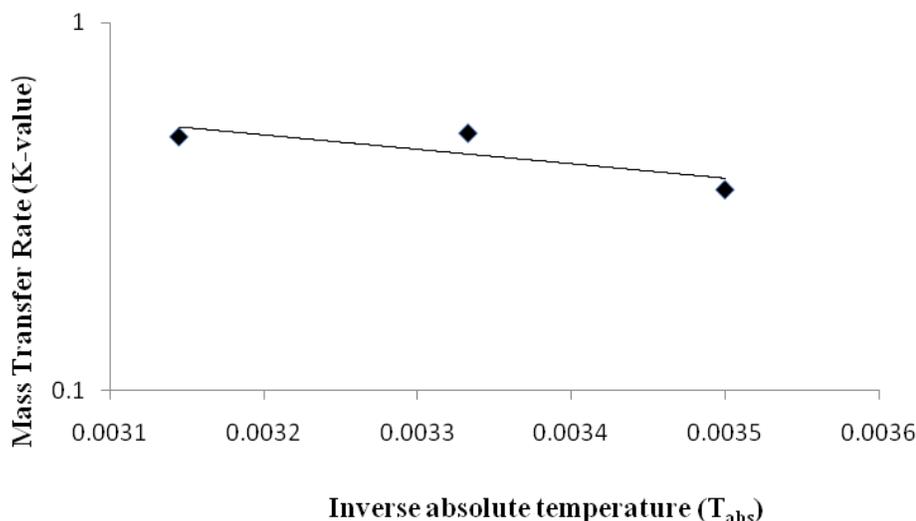


Fig. 4(b). Effect of temperature on mass transfer rate of mushroom at 20% salt solution.

From the equations, the activation energy is calculated as 1.796 kcal/ g-mole for 20% salt solution and 3.64 kcal/ g-mole for 15% salt solution. The values are much lower than the activation energy of sweet potato (12 kcal/g-mole) reported by Islam and Cowell (1989) but closer to those reported by Iqbal and Islam (2005) who found for cauliflower and cucumber 1.3 and 4.18 kcal/g-mole activation energy value respectively.

Summary and conclusion

Results showed that solution concentration and temperature of osmotic solution had a significant role in increasing water loss and solid gain. Statistical results reveals that moisture content deduce with increasing solid gain. Mass transfer co-efficient for various solution concentrations were calculated according to Fick's first law of diffusion. Activation energy was also observed.

Therefore, osmotic dehydration was found to be as an effective pretreatment method for reducing the moisture content for further drying.

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