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Rehydration kinetics of thin layer -dried red Amaranth (*Amaranthus tricolor* L.) leaves

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Abstract

The rehydration behaviour of a thin layer dried red Amaranth leaves were studied at various temperatures 38 ^{0}C, 50 ^{0}C, 60 ^{0}C and 80 ^{0}C. Three types of pretreated samples were used for this rehydration process: normal, chlorinated and processed. Pretreated samples were dried at 50 ^{0}C, 60 ^{0}C and 80 ^{0}C temperature. The rehydration process of the dried red amaranth leaves were satisfactorily described by the Peleg's equation. According to the Peleg's equation rehydration temperature increases from 38 ^{0}C to 80 ^{0}C, then the rate of rehydration constant K_1 significantly decreases and the capacity constant K_2 varies with different temperatures of rehydration. The increase in rehydration ratio was significant only as temperature increased from 38 ^{0}C to 80 ^{0}C.

Keywords

Red amaranth leaves, drying, rehydration, rehydration kinetics, Peleg's constant

Introduction

Amaranthus are the most important leafy vegetables of the lowland tropics of Asia and Africa. The nutritional quality of red Amaranth leaves is high, highly proteinaceous and rich in iron, calcium, vitamin-C and beta-carotene (11). Leafy vegetables are the sources of polyphenols, which prevent many chronic diseases, including cancer, cardiovascular disease and diabetes, has been well documented (12). Amaranth's leaves are an important source of antioxidants (13). Leafy vegetables are highly perishable. Hence, dehydration techniques are used to prevent nutritional losses. Drying prevents the texture, color and flavor losses of leafy vegetables due to low moisture content. Storage is very important to extend the self-life and get the best quality product. Now a day's dried foods are very trendy, and it's used as processed food or ready to- eat foods. Dehydrated products are mainly rehydrated when using the product. Rehydration or the water absorption characteristics is a process of moisturizing the dried product made by an abundant amount of water. Rehydration is influenced by some intrinsic factors such as chemical composition of the product, pre-drying treatment, dehydration process, moisture removal conditions and method of storage after drying. As well as some extrinsic factors like composition of dipping solution, condition of rehydration and temperature. During drying process the quality of the dehydrated products depends on the effects of chemical and physical changes in raw material. Dehydration and rehydration process is reversible when the pre-drying and post-drying product quality is almost the same. Immersion of dry material in water results in many changes due to water imbibitions and loss of solutes. The effectiveness of the rehydration process depends on the drying method and the pre-treatment process of the initial material. The rehydration rate depends on the rehydration method (shaking or agitation) and temperature and quantity of absorbed water. When the temperature increases the rehydration process is faster than the lower temperature due to quick cell wall and tissue disruption. The kinetic study is most important for understanding the rehydration process. It is important to know how water absorption can be accomplished and how it will be influenced by processed variables. It was described that the rehydration characteristics of some microwave-dried greens (2) and investigations on the effect of temperature on the rehydration behaviour of microwave-dried Amaranth (*Amaranthus dubius*) leaves (5). Studies on the characteristics of rehydrated-freeze-dried kiwi slices at different ratios of sample and distilled water (1). There are studies dealing with the effect of rehydration conditions on the rate of water absorption as well as the loss of soluble solids during rehydration.

Rehydration kinetics describes the mechanisms and the influence that certain process variables exert upon moisture transfer (1, 5, 10). During rehydration, a substantial amount of soluble solids can leach into the solution, affecting the nutritional quality of the products and the ability to imbibe water. The final retention of the dry matter does not influence the temperature of the rehydration medium.

In this study, we investigate the impacts at process factors like temperature with different pretreatments, for example, blanching and chlorinating. Likewise, the impact of drying conditions and rehydration temperature on rehydration kinetics are examined and a mathematical model portraying the mass transfer during rehydration process.

During rehydration the leaching process is described by the mathematical model namely Fick's second law. Now a days, the water uptake and the soluble solids losses during rehydration are described by the Weil bull probabilistic distribution, but during short rehydration, the product quality of the soluble solids is not studied yet. Some researchers reported that the compositions of the soluble materials discharging from vegetables, legumes are determined by using HPLC methods. Leached solids are sometimes contingent from a mass balance for the rehydration of vegetables. The rehydration kinetics of red Amaranth leaves were studied by the water absorbance of the dried leaves at four different temperatures (38 ^{0}C, 50 ^{0}C, 60 ^{0}C and 80 ^{0}C) and the rehydration curve was described by the moisture content as a function of time.

The mass transfer phenomena is described using the first-order kinetic model assuming

1. Temperature of water is constant
2. Initial moisture content of samples is uniform

$$d(X) / dt = - K_r (X - X_e) \quad \text{(Eqn. 1)}$$

Where,

X = Moisture content of the material during this process (kg/kg Dry basis)

Kr = Rate of rehydration (Per min),

Xe = Equilibrium moisture content of rehydrated material (kg/kg Dry basis)

T= Time period (min).

At saturation condition, the equilibrium moisture content was express as the water concentration. First order kinetics model was the best fitted model to express the experimental data and the result of this kinetic study. In this condition, the equilibrium moisture content is not equal to the moisture content of the fresh sample. This indicates that drying process is irreversible.

In this experimental condition, rehydration did not reach the higher moisture content, which means during drying structural damage and cell shrinkage occur. As a result, rehydration ability is decreases.

Mathematical model of rehydration kinetics

Rehydration kinetics

$$X = Xe - (Xi - Xe)\, e^{-krt} \quad \text{(Eqn. 2)}$$

Where,

X = Moisture content (kg/kg Dry basis)

Xe = Equilibrium moisture content (kg/kg Dry basis)

Kr = Rate constant of moisture loss (Per min)

Factors affecting the parameters

Rehydration conditions

Water temperature (T, ˚C)

$$K_r = K_0 (T/60)^n \quad \text{(Eqn. 3)}$$

$$X_e = X_0 (T/60)^m \quad \text{(Eqn. 4)}$$

Numerous analysts dealt with this topic. They did their research work on the rehydration kinetics of leafy vegetables, for example, dasheen leaves, west american pepper leaves, spinach, mint leaves, basil leaves, coriander leaves and so on (3-6, 16-18). In our study, we are using peleg's model to describe the rehydration kinetics of red amaranth leaves. Peleg's constants K_1 and K_2 were determine using Eqn. 5 and Eqn. 6.

$$M_t = M_0 \pm \frac{t}{K_1 + K_2 t} \quad \text{(Eqn. 5)}$$

$$\frac{t}{M_t - M_0} = K_1 + K_2 t \quad \text{(Eqn. 6)}$$

M_e was calculated from equation 7 using the value of K_2

$$M_e = M_0 + 1/K_2 \quad \text{(Eqn. 7)}$$

Materials and Methods

Preparation of sample for drying

Undamaged, matured fresh leaves of red Amaranth were taken, and then properly cleaned in tap water to remove foreign matters like mud, dirt, chaff and immature leaves. The surface moisture was removed by using a muslin cloth and after that, it air dried at room temperature. Then, the leaves were dried at 3 different temperatures 50 ^{0}C, 60 ^{0}C and 80 ^{0}C in a tray drier for 4 hrs.

Chlorinated sample

Red Amaranth leaves were dipped in chlorinated water (5 drop of Zeoline-200 in 1L distilled water) for 5 min. Then, the leaves were drained out and the surface water on the wet red amaranth leaves was removed with a muslin cloth. The red amaranth leaves were dried at 3 different temperature 50 ^{0}C, 60 ^{0}C and 80 ^{0}C in a tray drier for 4 hrs.

Water blanched sample

Red Amaranth leaves were blanched at 80 ^{0}C temperatures for 3 min. After that the blanched leaves were placed under running tap water immediately to cool in ambient temperature and the surface water on the wet leaves of red amaranth was removed with a muslin cloth. The red amaranth leaves were dried at 3 different temperatures 50 ^{0}C, 60 ^{0}C and 80 ^{0}C in a tray drier for 4 hrs. The samples obtained after drying at different temperatures were subjected for further studies.

Drying procedure

A laboratory scale tray dryer (International Commercial Traders, Model-SM502, Kolkata, India) was used to conduct this drying experiment. The experiments were conducted in three replications at 50 ^{0}C, 60 ^{0}C and 80 ^{0}C of drying air temperature. Red Amaranth leaves were spread uniformly on a tray. The mass loss of the sample was measured by using a digital weighing machine (Electronic Balance.mode:WJ302A, New-Delhi, India) with the accuracy of 0.01gm, at 15 min intervals.

Rehydration Procedure

Samples are dried at four different temperatures through thin layer drying process and the dehydrated samples are rehydrated in a temperature-controlled water bath shaker (manufactured by Sicco Instruments Pvt. Ltd., Kolkata, India) at a constant speed of 60 rpm at 38 ^{0}C, 50 ^{0}C, 60 ^{0}C and 80 ^{0}C temperature. For each experiment, 2 gm of dehydrated red amaranth leaves were used. Samples were rehydrated in 250 ml Erlenmeyer flasks containing 100 ml distilled water. Then, the beakers were put into a water bath and withdrawn after 15 min intervals. After specified soaking times, the hydrated leaves were blotted free of excess surface moisture with an absorbent cloth and then air-dried. After that, the weight was measured in a digital weighing machine. Calculate the weight difference to measure the water absorbance by the dehydrated sample. The capacity of dehydrated leaves to absorb moisture is defined as the rehydration ratio.

Mathematical modeling

For this rehydration, kinetic study we are using the linear form of Peleg's equation to fit the experimental data within the curvilinear segments of graphs obtained. The rehydration process was done until the difference between 2 consecutive weights was insignificant. The % of moisture content was expressed as the dry basis (% db). The rehydration ratio was calculated by the ratio between the weight of the rehydrated material and the weight of the dehydrated material, as described.

Results and Discussion

Rehydration is widely used as a parameter for dried sample quality, established that the physical and chemical changes during the dehydration process are influenced by sample composition, pre-treatment process and the processing conditions. The rehydration process shows that the rehydration ratios of dried chlorinated, water blanched and control samples at 60 ^{0}C are higher than those of dried ones at other temperatures. An increase in temperature above 60 ^{0}C had an adverse effect on the final rehydration ratio, which decreased with increasing temperature. It indicates the change in the product induced by temperature and perhaps a loss of solids during the rehydration process, reported that 60 ^{0}C convection dried potato slice gives the better result.

Fig. 1, Fig. 2 and Fig. 3 show the rehydration kinetics of red amaranth leaves at four different temperatures (38 ^{0}C, 50 ^{0}C, 60 ^{0}C and 80 ^{0}C) for 50 ^{0}C dried control, chlorinated and processed sample respectively. Fig. 4, Fig. 5 and Fig. 6 represent the rehydration kinetics of control, chlorinated and processed sample of red amaranth leaves dried at 60 ^{0}C and Fig. 7, Fig. 8 and Fig. 9 represents the same at 80 ^{0}C temperature dried sample. During rehydration, the water intake is more drastic during the first 33 min, then tapering off. Rehydration at 60 ^{0}C temperature shows the higher water absorbance and the chlorinated sample taken maximum amount of water and after rehydration it looks like the fresh one. Color, texture and the freshness is better than the other samples. So the overall acceptance of this rehydrated sample is higher.

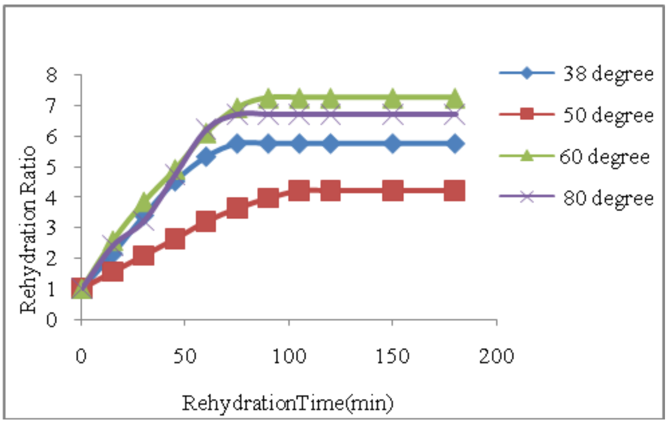

Fig. 1. Rehydration kinetics of red Amaranth leaves at different temperatures for 50 ^{0}C temperature dried Control sample.

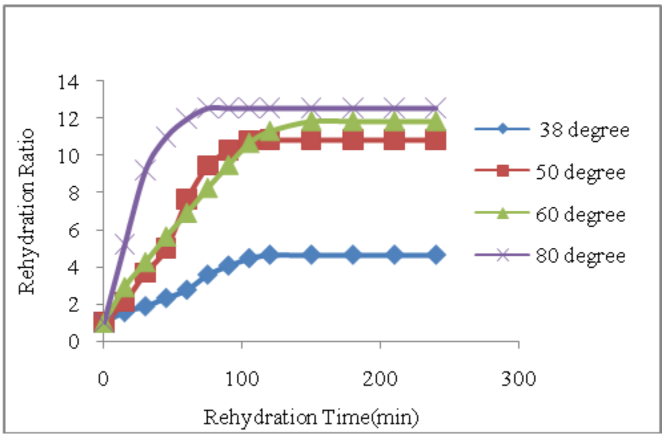

Fig. 2. Rehydration kinetics of red Amaranth leaves at different temperatures for 50 ^{0}C temperature dried Chlorinated sample.

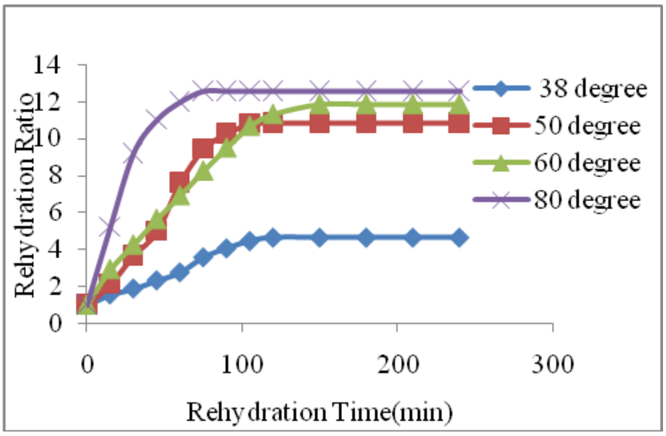

Fig. 3. Rehydration kinetics of red Amaranth leaves at different temperatures for 50 °C temperature dried processed sample.

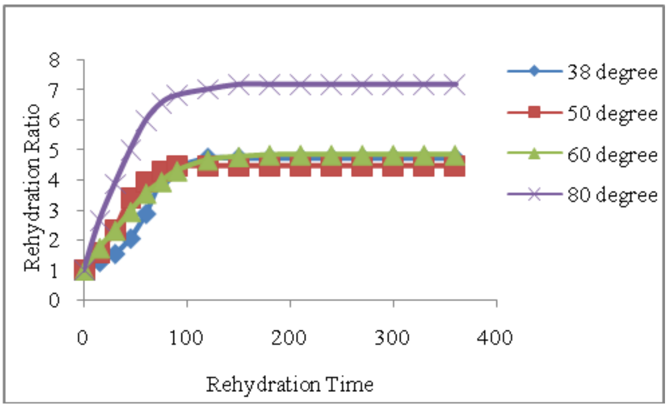

Fig. 4. Rehydration kinetics of red Amaranth leaves at different temperatures for 60 °C temperature dried control sample.

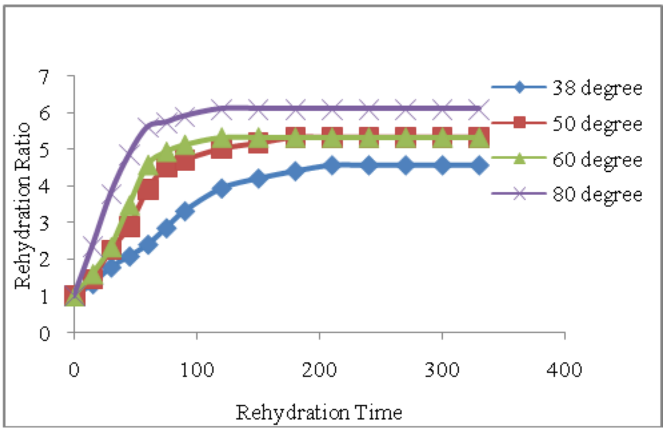

Fig. 5. Rehydration kinetics of red Amaranth leaves at different temperatures for 60 °C temperature dried chlorinated sample.

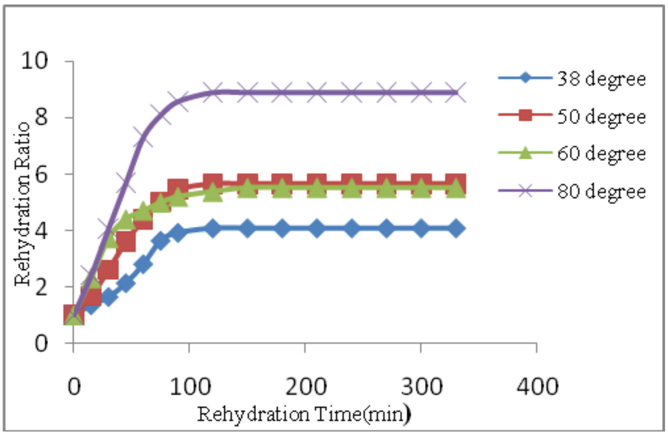

Fig. 6. Rehydration kinetics of red Amaranth leaves at different temperatures for 60 °C temperature dried processed sample.

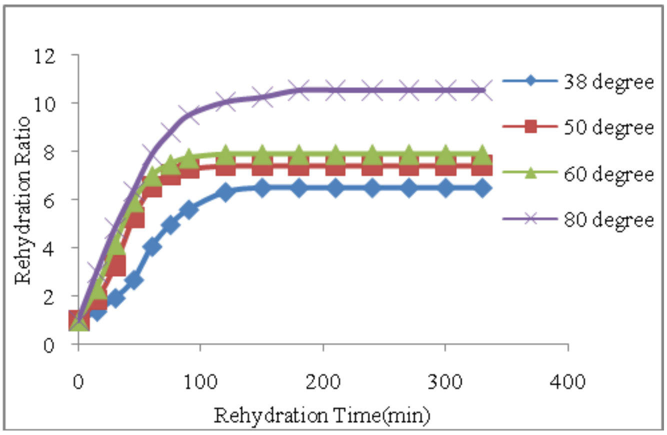

Fig. 7. Rehydration kinetics of red Amaranth leaves at different temperatures for 80 °C temperature dried control sample.

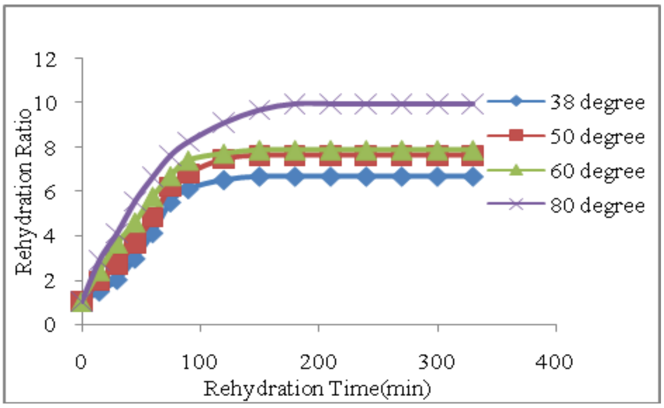

Fig. 8. Rehydration kinetics of red Amaranth leaves at different temperatures for 80 °C temperature dried chlorinated sample.

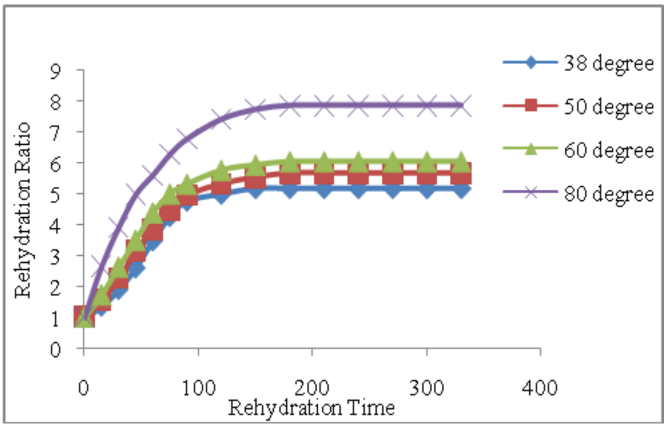

Fig. 9. Rehydration kinetics of red Amaranth leaves at different temperatures for 80 °C temperature dried processed sample.

Table 1 shows the Peleg rate constant (K_1) and Peleg capacity constant (K_2) for every rehydration process for four different rehydration temperature and its graphical representation based on $t/$ (M_0-M_e) versus time (t) ploted. The major advantage of the Peleg model is to predict equilibrium moisture content using short-time experimental data and selected for calculating the values of Peleg rate constant (K_1) and Peleg capacity constant (K_2) which affects the results we obtained (17). When the rehydration temperature is increased, the Peleg rate constant (K_1) and the Peleg capacity constant (K_2) both are consequently decreased, and this phenomenon effects the temperature, which is significant ($p \leq .05$) as increasing the temperature from 50 °C to 60 °C.

Table 1. Result's for peleg model for Red Amaranth leaves rehydration at 38 ^{0}C-80 ^{0}C temperature

Sample	Pretreatment	Rehydration Temperature	R^2 value	K_1Value	K_2 Value
50 ^{0}C temperature dried sample	Control	38°C	0.961	0.773	3 x 10^{-3}
		50°C	0.978	0.350	2.3 x 10^{-3}
		60°C	0.977	0.319	1.9 x 10^{-3}
		80°C	0.968	0.372	1.8 x 10^{-3}
	Chlorinated	38°C	0.897	1.152	2.7 x 10^{-3}
		50°C	0.951	1.073	2.9 x10^{-3}
		60°C	0.996	0.095	1.2 x 10^{-3}
		80°C	0.936	0.540	1.2 x 10^{-3}
	Processed	38°C	0.842	2.651	1.8 x 10^{-3}
		50°C	0.966	1.022	1.9 x 10^{-3}
		60°C	0.990	0.482	2 x 10^{-3}
		80°C	0.990	0.428	2.1 x 10^{-3}
60 ^{0}C temperature dried sample	Control	38°C	0.972	1.024	2.8 x 10^{-3}
		50°C	0.973	0.784	1.7 x 10^{-3}
		60°C	0.971	0.714	1.6x 10^{-3}
		80°C	0.988	0.495	1.4x 10^{-3}
	Chlorinated	38°C	0.973	1.390	2.8 x 10^{-3}
		50°C	0.987	0.750	2.6x 10^{-3}
		60°C	0.989	0.526	2.6x 10^{-3}
		80°C	0.996	0.264	2.4x 10^{-3}
	Processed	38°C	0.984	0.908	3.5x 10^{-3}
		50°C	0.989	0.552	2.5x 10^{-3}
		60°C	0.997	0.315	2.7x 10^{-3}
		80°C	0.988	0.352	1.6x 10^{-3}
80 ^{0}C temperature dried sample	Control	38°C	0.957	1.366	2.8x 10^{-3}
		50°C	0.985	0.557	2.7x 10^{-3}
		60°C	0.992	0.408	2.6x 10^{-3}
		80°C	0.990	0.487	1.9x 10^{-3}
	Chlorinated	38°C	0.959	1.313	2.9x 10^{-3}
		50°C	0.974	0.986	2.6x 10^{-3}
		60°C	0.989	0.649	2.7x 10^{-3}
		80°C	0.987	0.68	2.1x 10^{-3}
	Processed	38°C	0.978	1.034	3.1x 10^{-3}
		50°C	0.985	0.903	2.8x 10^{-3}
		60°C	0.988	0.742	2.7x 10^{-3}
		80°C	0.993	0.506	2.1x 10^{-3}

Conclusion

The rehydration ratio is higher at 60 ^{0}C temperature for dried chlorinated, processed and control samples. An increase in temperature above 60 ^{0}C had an adverse effect on the final rehydration ratio value, and it is decreased with increasing temperature. It is indicated that during the rehydration process temperature-induced to change the product and the loss of solids.

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Authors contributions

Both the authors have carried out the research work and participated in manuscript preparation.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

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