RESEARCH ARTICLE

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Effect of Pre-Treatment on Drying of Red Amaranth and Its Utilization in Noodles Preparation

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ABSTRACT

Red amaranth is a perishable, colored leafy vegetable that can be preserved through a variety of methods, including dehydration. The current study was conducted to investigate the effect of pre-treatments (blanching, sulphitation, and blanching plus sulphitation) and drying methods (cabinet and solar) on the drying rate and color intensity of red amaranth (leaves and stems) and the development of red amaranth enriched noodles. Drying rate and color intensity were varied in different degrees based on the applied pre-treatment and drying method. For drying red amaranth leaves, blanching plus sulphitation followed by cabinet drying showed the highest drying rate (0.67 h^{-1}), whereas blanching followed by cabinet drying showed the fastest drying rate (0.69 h^{-1}) for red amaranth stems. Color absorbance study revealed that sulphitation pre-treatment and cabinet drying lead highest color absorbance (0.261) in red amaranth leaves while blanching and cabinet drying provides the highest color intensity (0.121) in stems. The use of red amaranth leaves powder in noodles preparation at 5% and 10% wheat flour substitutions gave significantly different ($p<0.05$) sensory parameters. Substitution of 5% wheat flour by sulphited and cabinet dried red amaranth leaves powder gave the highest overall acceptability of developed noodles.

Keywords: Drying, Noodles, Pre-Treatments, Red Amaranth.

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I. Introduction

Red amaranth (Amaranthus tricolor L.) often known as 'Lal Shak' in Bengali, is a member of the Amaranthaceae family and one of the leafiest vegetables in Bangladesh. It is an ornamental crop native to Asia, now widely cultivated across the tropics as a vegetable. It is a good source of vitamin-A, K, B6, C, riboflavin, folate, and dietary minerals such as calcium, iron, magnesium, phosphorus, potassium, zinc, copper etc. [1], [2]. Despite being an abundant source of nutrients, this vegetable is only available in all seasons at a fresh state. Red amaranth is a highly perishable vegetable due to its high moisture content. In Bangladesh, about 25-30% red amaranth decay due to a lack of proper transportation, storage and processing facilities [3]. So, it is necessary to introduce some farmer's friendly and economical preservation techniques to make it available year-round as well as to prevent the spoilage or wastage. Dried foods with outstanding nutritional and organoleptic properties that are nearly equivalent to those of fresh products are now one of the highest market demands.

Drying is a traditional preservation technique that turns vegetables into a lighter and portable product [4]–[6]. Drying destroys enzymes and microbes, evaporated moisture thus extends the shelf life of products [5]. There are a variety of drying methods available. However, in tropical and subtropical regions, open sun drying is the most prevalent method [7]. It is highly reliant on the weather, thus the product is much more vulnerable to contamination. Furthermore, uncontrolled drying rates leads poor quality product. As a result, the concept of solar dryers has arisen in order to improve the quality of the dried product in comparison to traditional techniques. Solar drying provides better color, flavor, and nutritional quality of products over conventional sun drying methods [1], [8]. Cabinet drying is a more efficient mechanical drying process in which heat and mass transfer can be optimized to attain maximum quality of the product. However, in all drying methods some undesirable changes like degradation of color, flavor, and texture etc., might happen in varying degrees. Some of these undesirable changes have been studied to be mitigated by pre-treatments before drying [5], [9]–[11].

A number of pre-treatments can be employed depending on the food to be dried and its end-use. One of the most widely used pre-treatment techniques in the food industry is blanching [1], [12], [13]. It inactivates enzymes, soften tissue, and prevent color and flavor loss during processing or storage. During blanching product must be heated to a high enough temperature, below the boiling point of water, for several minutes. However, blanching may cause some nutrient loss, including water-soluble vitamins and solids like carbohydrates, amino acids, and minerals [7]. But potassium meta-bisulphite pre-treatment increases drying rate decreases color degradation during drying and improves textural properties [12], [14], [15]. However, no detailed studies were found in the literature on the effect of pre-treatments on the drying behavior of red amaranth. Therefore, the objectives of this study were: (a) to evaluate the effect of pre-treatments on the quality of dehydrated red amaranth; and (b) to assess the sensory quality of prepared noodles using red amaranth powder.

II. Materials and Methods

A. Raw Materials

Red amaranth and other ingredients required for noodles preparation were purchased from the local market of Bangladesh Agricultural University, Mymensingh, Bangladesh. Red amaranth stems were trimmed from leaves and chopped in 2-3 cm. Roots, damaged stems, and leaves were removed. Finally, sorted red amaranth leaves and stems were carefully rinsed in cold water to remove adherent dust and dirt.

B. Pre-treatments

All the cleaned, chopped stems and leaves were subjected to different pre-treatments, viz., blanching, sulphitation, and blanching plus sulphitation.

In blanching, leaves and stems were wrapped in a muslin cloth and soaked in boiling water (90 °C) for two minutes, then strained excess water. The red amaranth stems and leaves were sulphited with 2% KMS solution in a jar with a perforated plate at the top. After water blanching, 2% KMS treatment was performed on amaranth samples in the blanching plus sulphitation pretreatment. Cleaned red amaranth stems and leaves without any pre-treatment were considered as control.

C. Drying Experiments

Pre-treated red amaranth samples were dried using solar and cabinet dryers. The cabinet dryer (Model: OV-165, GallenKamp Company, United Kingdom) consists of several chambers in which sample trays (3-4 cm thick layer of leaves, 1-1.5 cm long single layer stems) were placed.

Control and pre-treated samples were dried on both sides at constant air velocity (0.6 m/sec) and dry bulb temperature (60 °C). The solar dryer consists of several sections in which the sample trays were placed when the sun was shining (Fig. 1). The temperature was measured at different times during the drying, and the mean drying temperature was recorded 78 °C.

In both drying methods, moisture loss of samples was measured gravimetrically until the product gained constant weight.

Fig. 1. Drying of red amaranth in greenhouse-based solar dryer

Since food dehydration is thought to occur by diffusion, Fick's second law of diffusion was utilized to describe mass transfer during drying. For one-dimensional transport, Fick's law was described as follows [4], [16], [17]:

$$MR = \frac{8}{\pi^2} \exp \frac{-\pi^2 D_e t}{L^2} = \frac{8}{\pi^2} \exp(-kt) \qquad (1)$$

Where, $k = \frac{\pi^2 D_e}{L^2}$= drying rate constant, MR= moisture ratio (ratio of moisture content at any given time to the initial moisture content).

By plotting MR, against drying time, t, the drying rate constant, k was obtained as line slope.

D. Preparation of Red Amaranth Powder

Dried red amaranth leaves and stems were grinded in a grinder to obtain a powder. The ground powder was sieved, packed, and stored for further use. The powder obtained from different pre-treatments and drying methods was packaged in plastic bags and stored in a refrigerator for future use.

E. Preparation of Red Amaranth Enriched Noodles

Table I shows the basic formulation for making composite flour noodles. Five noodle samples were made by partially substituting wheat flour with various percentages of red amaranth leaves powder (0, 5, and 10%). The wheat flour, red amaranth powder, and all other ingredients were weighted as per formulation. All the ingredients were mixed with boiled water and kneaded for 10 minutes to prepare the dough which was then transferred to a vertical noodles-making machine. The prepared raw noodles were steamed at 100 °C for 2 minutes for partial gelatinization and pasteurization of noodles. The noodles were then dried for 4 hours at 60 °C in the cabinet dryer. The cooled and dried noodles were packaged in 100 g polythene bags and stored in a dry and cool environment until used.

TABLE I: Basic Formulation for the Red Amaranth Fortified Noodles (on the Basis of 100 g Composite Flour)

Ingredients	Sample				
	C	S_1	S_2	S_3	S_4
Wheat Flour (g)	100	95	90	95	90
Red amaranth leaves powder (g)	0	5	10	5	10
Onion powder (g)	0.5	0.5	0.5	0.5	0.5
Garlic powder (g)	0.1	0.1	0.1	0.1	0.1
Cumin powder (g)	0.5	0.5	0.5	0.5	0.5
Zinger juice (ml)	1	1	1	1	1
Oil (ml)	10	10	10	10	10
Egg (ml)	20	20	20	20	20
Citric acid (g)	0.1	0.1	0.1	0.1	0.1
Sodium bicarbonate ($NaHCO_3$)(g)	1	1	1	1	1
Starch (g)	2	2	2	2	2
Salt (NaCl) (g)	1	1	1	1	1
Boiling water (ml)	5	5	5	5	5

C=control noodles with wheat flour only; S_1=noodles with 5% sulphited and cabinet dried red amaranth leaves powder; S_2= noodles with 10% sulphited and cabinet dried red amaranth leaves powder; S_3= noodles with 5% blanched and solar dried red amaranth leaves powder; S_4= noodles with 10% blanched and solar dried red amaranth leaves powder.

F. Composition Analysis

The proximate composition (moisture, fat, protein, ash, and fiber) and Vitamin-C of fresh red amaranth leaves and stems were determined by AOAC methods [18]. All the chemicals used in the present research work were of analytical grade. By deducting the measured protein, moisture, fat, and ash from 100, the total carbohydrates were computed approximately. [9], [19], [20].

G. Measurement of Color Intensity

The dried red amaranth leaves and stems powder were investigated to observe the color intensity. First, a 5% sample solution was prepared by mixing 5 ml powder in 95 ml distilled water. Then the solution was taken into a mechanical shaker (Model-GFL 3017, Germany) and shaken for 60 minutes at 180 rpm. Then the solution was filtered by filter paper and transferred into test tubes. After that, the solution was taken into a centrifugal separator (Model-EBA 21, Germany) and centrifuged at 5500 rpm for 10 minutes. Then 2 ml solutions were taken into a spectrophotometer (model-336001 USA), and a 620 nm wavelength monochromatic light passed through the solution. The absorbed light and passed light ratio (color intensity) were observed in the spectrophotometer screen. A blank test was also done for the calibration of the device.

H. Sensory Analysis

The consumer acceptability of noodles enriched with red amaranth leaves powder was evaluated by panel testing. The hedonic rating test was used to determine the acceptability. The semi-trained panelists were chosen randomly and asked to rate numerically coded samples. The panelists rated their acceptability of the product on a 1-9 point hedonic scale. The scale was arranged such that 9= like extremely and 1= dislike extremely [19], [21],[22].

I. Statistical Analysis

The sensory assessment data were evaluated using a two-way analysis of variance (ANOVA) and the SAS (Statistical Analysis System) mean technique. To obtain mean differences, Duncan's New Multiple Range Test (DMRT) was used. Statistical analyses were performed using the WASP2 statistical online package software and STAR (Statistical Tools for Agricultural Research).

III. Result and Discussion

A. Proximate Composition of Red Amaranth

The proximate compositions of fresh red amaranth leaves and stems are given in Table II. The moisture content of red amaranth leaves (90%) and stems (90.3%) was found quite nearer. Red amaranth leaves showed a higher amount of protein (3.2%), fat (0.3%), and Vitamin-C content (59 mg/100 g) in comparison to red amaranth stems. However, red amaranth stems showed a slightly higher amount of ash (2.94%) and fiber (0.98%). It was reported that tender red amaranth has 92.5% moisture, 1.8% ash, 1.2% fiber, 0.9% protein and 0.1% fat [23]. Proximate compositions of red amaranth are nearer to the observation reported in previous studies [2], [24]–[26]. The minor variations in this study might be due to the varietal difference, maturity, fertilizer used, etc.

TABLE II: Proximate Composition of Fresh Red Amaranth

Composition	Leaves	Stems
Moisture (%wb)	90±1.41	90.3±0.55
Ash (%)	2.70±0.07	2.94±0.04
Protein (%)	3.2±0.32	2.8±0.03
Fat (%)	0.3±0.0	0.2±0.0
Crude fiber (%)	0.90±0.01	0.98±0.01
Vitamin-C (mg/100 g)	59±0.05	43±0.04

Values are mean ± SD of three samples

B. Effect of Pre-treatment and Drying Methods on Drying Rate

Red amaranth leaves and stems were pre-treated and dried in a cabinet and solar dryer. After each pre-treatment, initial moisture content was measured and water loss during drying was recorded at specific time intervals. By plotting the moisture ratio against time, the drying curve and corresponding equations were obtained. The drying curve of red amaranth leaves during cabinet drying is shown in Fig. 2.

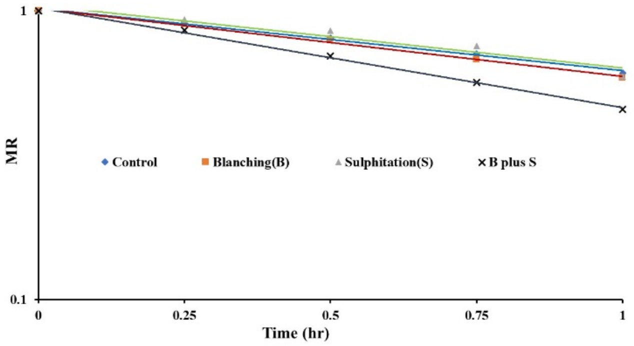

Fig. 2. Drying curve of red amaranth leaves during cabinet drying at 60°C.

TABLE III: EFFECT OF PRE-TREATMENT AND DRYING METHODS ON DRYING RATE OF RED AMARANTH

Pre-treatment	Drying rate of leaves (h^{-1})		Drying rate of stems (h^{-1})	
	Cabinet drying	Solar drying	Cabinet drying	Solar drying
Control	0.49	0.46	0.43	0.41
Blanching (B)	0.54	0.37	0.69	0.5
Sulphitation (S)	0.5	0.42	0.62	0.45
B+S	0.67	0.52	0.54	0.54

It was observed that pre-treatments influenced the drying kinetics of red amaranth leaves and stems. The influence of pre-treatments and drying methods on the drying rate of red amaranth leaves and stems are presented in Table III.

In cabinet drying of red amaranth leaves blanched plus sulphited sample showed the highest drying rate (0.67 h^{-1}), followed by blanched sample (0.54 h^{-1}) and sulphites sample (0.5 h^{-1}). In cabinet drying of red amaranth stems, blanching showed overall highest drying rate (0.69 h^{-1}) followed by sulphitation (0.62 h^{-1}) and blanching plus sulphitation (0.54 h^{-1}). However, in both cases (cabinet drying of leaves and cabinet drying of stems) control samples showed lowest drying rates.

In solar drying of red amaranth leaves combined pre-treatments (B+S) showed the highest drying rate (0.52 h^{-1}) followed by control (0.46 h-1) and sulphited sample (0.42 h^{-1}). In contrast to cabinet drying, blanched red amaranth leaves showed the lowest drying rate (0.37 h^{-1}) in solar drying. In solar drying of red amaranth stems, the blanched plus sulphited sample showed highest drying rate (0.54 h^{-1}) followed by the blanched sample (0.5 h^{-1}) and sulphited sample (0.45 h^{-1}). As like in cabinet drying, control sample showed lowest drying rate (0.41 h^{-1}) in solar drying over other pre-treatments.

In brief, for faster drying of red amaranth leaves, blanching plus sulphitation followed by cabinet drying was found to be best over other pre-treatments and drying combinations. Additionally, blanching followed by cabinet drying was found to be best combination to obtain dry red amaranth stems in shortest possible time over other studied pre-treatments and drying combinations.

Several researchers investigated the influence of pre-treatments and drying methods on different vegetables [2], [7], [27]. Pre-treatment tomatoes with CaCl2 showed 20% faster convective drying [27]. Blanching pre-treatment showed a significant increase in the drying rate of green chili during hot air drying [28]. The influence of pre-treatments on drying rate depends on the dose, duration, and applied methods [16], [29].

C. Effect of Pre-treatment and Drying Methods on the Color Intensity of Powder

The color intensity of dried red amaranth leaves and stem powder varied depending on pre-treatments and drying methods (Table IV). In cabinet drying of red amaranth leaves, the highest color intensity was measured in sulphited sample (0.261) whereas the lowest intensity was measured in the blanched plus sulphited sample (0.105). In cabinet drying of red amaranth stems, blanching provided the highest color intensity (0.121) followed by blanching plus sulphitation (0.101) and sulphitation (0.096). Highest color intensity in sulphited samples is due to the prevention of enzymatic discoloration by KMS [29]. In solar drying of red amaranth leaves only blanching provided better color intensity (0.172) over the control sample (0.147). In solar drying of red amaranth stems only combined pre-treatment (B plus S) showed slightly higher color intensity (0.091) over the control sample (0.081). However, during solar drying of leaves or stems sulphitation gave the lowest color intensity of samples.

TABLE IV: EFFECT OF PRETREATMENT AND DRYING METHODS ON COLOR INTENSITY OF RED AMARANTH POWDER

Drying Methods	Treatments	Absorbance	
		Leaves	Stem
Cabinet Drying	Control	0.244^{b}	0.085^{h}
	Blanching (B)	0.209^{c}	0.121^{d}
	Sulphitation (S)	0.261^{a}	0.096^{g}
	B + S	0.105^{e}	0.101^{f}
Solar Drying	Control	0.147^{b}	0.081^{e}
	Blanching (B)	0.172^{a}	0.071^{g}
	Sulphitation (S)	0.072^{f}	0.065^{h}
	B + S	0.096^{c}	0.091^{d}

*The superscript alphabets indicate chronologically descending color intensities.

D. Sensory Evaluation of Red Amaranth Enriched Composite Flour Noodles

Based on the color intensity study, the two highest color-intensive red amaranth leaves powder (one from cabinet dried and another from solar-dried) were chosen as wheat flour substitute to prepare composite flour noodles. The sulphited and cabinet-dried red amaranth leaves to powder and blanched and solar-dried leaves powder were added with wheat flour at 5% and 10% levels to obtain colored noodles. The mean score for color, flavor, texture, and overall acceptability of different samples are presented in Table V. Sensory properties of composite noodles varied significantly in terms of color, flavor, texture, and overall acceptability.

TABLE V: EFFECT OF RED AMARANTH LEAVES POWDER INCORPORATION ON THE SENSORY ACCEPTABILITY OF NOODLES

Noodles Type	Mean scores of sensory attributes			
	Color	Flavor	Texture	Overall acceptability
C	7.30^{ab}	6.90^{a}	6.50^{b}	6.70^{c}
S_1	7.80^{a}	7.80^{a}	7.50^{a}	8.20^{a}
S_2	7.10^{bc}	7.10^{a}	8.00^{a}	7.50^{b}
S_3	7.60^{ab}	7.60^{a}	7.30^{a}	$7.3b^{c}$
S_4	6.50^{c}	7.00^{a}	7.70^{a}	6.90^{bc}
LSD (<0.05)	0.658	0.658	0.795	0.670
CV	9.958%	13.558%	11.958%	10.221%

*Values with different superscript differ significantly within the column at p<0.05.

There is a significant difference in samples S_1 and S_2 at ($P<0.05$) in terms of color acceptance. In terms of color acceptance, there is a significant difference in samples S1 and S_2 at ($P<0.05$). A significant difference was also found between samples S_3 and S_4. The highest color score was obtained in S_1 (7.80) and the lowest score in S_4 (6.50), whereas score of the control sample was 7.30.

The flavor score of all composite flour noodles was higher than the control, and there was no significant difference among treatments and control. The noodle containing 5% sulphited and cabinet dried leaves powder (S_1) gave the highest score (7.80), and the noodle containing only wheat flour (C) secured the lowest score (6.90). The flavor score was 7.10, 7.60, and 7.00 of samples S_2, S_3, and S_4, respectively.

The sensory texture score of all composite flour noodles was higher than the control noodle. The range of texture score of noodles was 6.50-8.00. The highest score was obtained by sample S_2, and the lowest score was obtained by sample C. The other scores were 7.50, 7.30 and 7.70 for sample S_1, S_3 and S_4 respectively. There was a significant difference ($P<0.05$) between control and any other treatment.

The highest overall acceptability score was 8.20 in S_1, and the lowest score was 6.90 in S_4. The score of the samples S_2 and S_3 were 7.50 and 7.30, respectively. Except S_4, all samples were found significantly different from each other ($P<0.05$). ANOVA analysis suggested that the noodle sample S_1 was the best which was prepared with incorporation of 5% sulphited and cabinet dried red amaranth leaves powder.

IV. Conclusion

Red amaranth leaves contain a higher amount of protein, fat, and vitamin-C content in comparison to stems. Drying rate and color change of red amaranth leaves and stems are closely related to drying methods and pre-treatments. Without any pre-treatment, cabinet drying (at 60 °C) provided a faster drying rate for red amaranth leaves and stems than the solar drying method. Different pre-treatments (blanching, sulphitation, blanching plus sulphitation) greatly influenced the drying rate of red amaranth leaves and stems, whereas the highest drying rate was obtained in blanched stems followed by cabinet drying. Blanching plus sulphitation followed by cabinet drying was found best methods for drying of red amaranth leaves in terms of drying rate. In cabinet drying method, the highest color intensity was found in sulphited red amaranth leaves powder, whereas in solar drying method, the highest color intensity measured in blanched leaves powder. The sensory acceptability of red amaranth leaves powder incorporated noodles varied significantly with the variation of substitution level. Noodles prepared with 5% red amaranth leaves powder obtained by sulphitation pre-treatment followed by cabinet dried showed highest overall acceptability.

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