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STUDIES ON THE DEHYDRATION AND REHYDRATION CHARACTERISTICS OF 'BHES' (NYMPHAEA LOTUS L)

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Abstract. Freshly harvested roots of *Nymphaea lotus* L. (Bhes) were prepared by slicing into rings and cuttings into pieces, and dehydrated to 6.5 and 7.8% final moisture contents respectively. The rings showed higher drying rates and better rehydration ratios as compared to the pieces. Sulphur-house treated samples (both rings and pieces) were subjectively rated to be better than the liquid sulphited samples as far as colour of the stored Bhes was concerned. However, sulphur-house sulphiting did not show any favourable effect on flavour of the samples. Though ascorbic acid, sulphur dioxide content and rehydration ratios gradually decreased during 240-day storage of the dehydrated Bhes, yet the product remained acceptable for eight months and rehydrated to almost original size and shape.

Nymphaea lotus L. is a submerged plant that grows in damp places and muddy areas of Pakistan. The roots of lotus, locally known as Bhes or Barsanda are used as a cooked starchy vegetable in large areas of the country. Meat-like flavour of the cooked Bhes is very much relished by the common populace of Pakistan.

Bhes are cylindrical roots 20-50 cm long and 2 - 3 cm dia. They are characterised by a number of air-passages running from end to end. Freshly harvested light brown roots turn darker on storage and become dark brown on cooking. The roots are either sliced into 0.5-cm thick rings or cut into pieces of 2.5-cm length before they are cooked or fried in ghee.

Bhes are available in large quantities during a very short period of winter (between last week of December and first week of January) and sell at very low prices. It would be appropriate to preserve this delicious vegetable during the period of glut, so that the surplus is utilized and is made available to the consumer during the rest of the year. Investigations were carried out to study the dehydration and rehydration characteristics of this vegetable and storage stability of dehydrated Bhes.

Materials and Methods

Preparation of the Vegetable. Freshly harvested undamaged Bhes were acquired from the local market, washed, divided into two equal lots (A and B) and prepared as: (A) the roots were sliced into 0.5 cm thick rings; and (B) the roots were halved longitudinally and cut into 2.5 cm long pieces.

Blanching. Prepared rings and pieces were steam-blanched for 3 and 5 min respectively. Blanching time was determined by checking the peroxidase activity. The activity of the enzyme was estimated by the method of Masure and Campbell[1].

Sulphiting. After blanching samples A and B were further divided into three equal parts (A_1, A_2, A_3 and B_1, B_2, B_3.) Samples A_1 and B_1 were spread on trays at the rate of 8 kg/m^2. The trays were placed in the sulphur house. Thirty g sulphur powder was burnt for 90 min. while subsequently the samples remained in the house for an additional time of 30 min. Samples A_2 and B_2 were dipped into 1.0% sodium sulphite solution at 60°C for 50-60 sec. No sulphiting treatment was applied to samples A_3 and B_3 (control).

Dehydration. All the samples were loaded onto trays at the rate of 8 kg/m^2 and placed in a cabinet type dehydrator (model No. 6298/59, Manchester). The drying temperature at dry bulb was 90, 80, 70 and 60°C and the drying time was 30, 30, 30 and 210 min respectively.

The optimum drying conditions were determined after a series of preliminary experiments. The results of averages of triplicate observations are reported in Table 1.

Drying Rate Calculations. Four trays, two each from A and B, were selected. Average weight of the two trays from each lot was used for drying rate calculations. Net weight of the samples was determined initially and at 30 min intervals during whole of drying operaton. Drying rate curves were drawn as described by Van Arsdel and Copley[2].

Quality Evaluation and Chemical Analysis. Dehydrated samples were packed in polyethylene pouches, stored at ambient temperature up to a storage time of 240 days, periodically drawn and analysed for moisture,[3] ascorbic acid,[4] sulphur dioxide content[5] and rehydration characteristics. The samples were rehydrated by boiling them in water for 6 min[6] and rehydration ratios calculated using the following relationship:[7]

Rehydration ratio =

Wt. rehydrated sample-wt. dry sample-Wt. dry sample.

Rehydrated fried Bhes were served to a panel of experienced judges, who were requested to arrange the samples in order of preference keeping in view the characteristics of fresh fried Bhes.

Results and Discussion

Determination of Optimum Drying Conditions

Preliminary experiments were conducted to determine suitable drying temperatures, so that dehydrated

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Bhes of acceptable quality were produced. Development of darkbrown colour in the finished product and comparatively low rehydration ratios (R.R.) of samples dried at temperatures generally used for most of the vegetables, were the two major problems to be tackled with. Experiments conducted to achieve dehydrated Bhes of acceptable quality revealed that it was necessary to dehydrate the samples at fairly low temperatures (Table 1). However, low dehydration temperature (to produce dried Bhes of desired moisture level of about 7.0%) resulted in a prolonged drying time (Table 1). Moreover, a thick gummy mass oozed out of the drying material during low temperature dehydration. This gummy material formed a protective layer on the surfaces of the drying rings and pieces, which might also have contributed in slowing down of moisture removal. The nature of gummy material was not investigated, as it was beyond the scope of present studies. Consequently such a drying schedule was established, which in a shortest possible time produced the finished product of acceptable quality, desired final moisture content and of better rehydration characteristics.

Fffect of Method of Sample Preparation on Drying Rates of Bhes

Sample A (rings) showed faster drying rates as compared to sample B (pieces). This phenomenon was observed from the very beginning of dehydration operation. Though the drying rate difference in the two samples was observed throughout the dehydration process, yet the gap narrowed towards the end of dehydration process (Fig 1). The higher drying rates in case of sample A might have been due to two reasons: (i) size of the prepared Bhes — sample A had more exposed surface area as compared to the sample B and (ii) shape of the samples — sample B was prepared by cutting the vegetable longitudinally and the air-passages were not fully exposed, while the air-passages in case of sample A were fully exposed.

Effect of Dehydration and Storage on the Quality of Bhes

Moisture Content. The moisture content of Bhes is given in Table 2 Sample A had smaller size and was more exposed through air-passages than sample B. therefore, it was dehydrated to lower final moisture content

Both the samples showed an increase in moisture content during 240-day storage at ambient temperature. At the termination of storage the rings showed 7.7% increase in moisture level, while the increase in case of pieces was 5.1%. This indicates that the rates of water absorption in these samples were not significantly different.

Ascorbic Acid. Fresh Bhes contained 6.5 mg/100g (dry weight basis) of ascorbic acid, which on dehydration decrease to 2.3 mg/100g and 2.6 mg/100 g in samples A and B respectively (Table 2 b). Higher amount of ascorbic acid retention in sample B may be due to shape and higher final moisture content of the pieces. As lesser is the moisture content of the end-product, adverse is the effect of drying heat on ascorbic acid. However, loss of this vitamin during storage was higher in the pieces than in the rings. This may be due to higher amount of the vitamin initially retained and comparatively higher quantity of moisture content (available for degredation reactions) in the pieces. Consequently, at the termination of the experiment (after 240-day storage) each of the samples could retain 30.8% of the total ascorbic acid present in fresh samples.

TABLE 1. TIME-TEMPRATURE DETERMINATION FOR DEHYDRATION OF BHES.

Drying temperature dry bulb(C)	Drying time (min)	Moisture %	Quality of dehydrated product*
90	240	7.4	Unacceptable
80	360	6.9	"
70	420	7.1	Acceptable
60	480	7.2	"

* Dehydrated samples were organoleptically evaluated for their colour, flavour, appearance and taste by a panel of expert judges.

TABLE 2. EFFECT OF METHOD OF PREPARATION AND STORAGE TIME ON MOISTURE-CONTENT, ASCORBIC ACID AND REHYDRATION RATIOS OF DEHYDRATED BHES.

Sample	Fresh	Dehydrated					
		Storage Time					
		0	60	120	180	240	
Moisture Content (%).							
Rings	81.0	6.5	6.7	6.8	7.0	7.0	
Pieces	81.0	7.8	8.1	8.2	8.2	8.2	
Ascorbic Acid (mg/100g dry wt. basis)							
Rings	6.5	2.3	2.2	2.1	2.1	2.0	
Pieces	6.5	2.6	2.4	2.2	2.1	2.0	
Rehydration Ratios							
Rings	—	6.4	6.3	6.3	6.3	6.2	
Pieces	—	6.0	6.0	5.9	5.8	5.9	

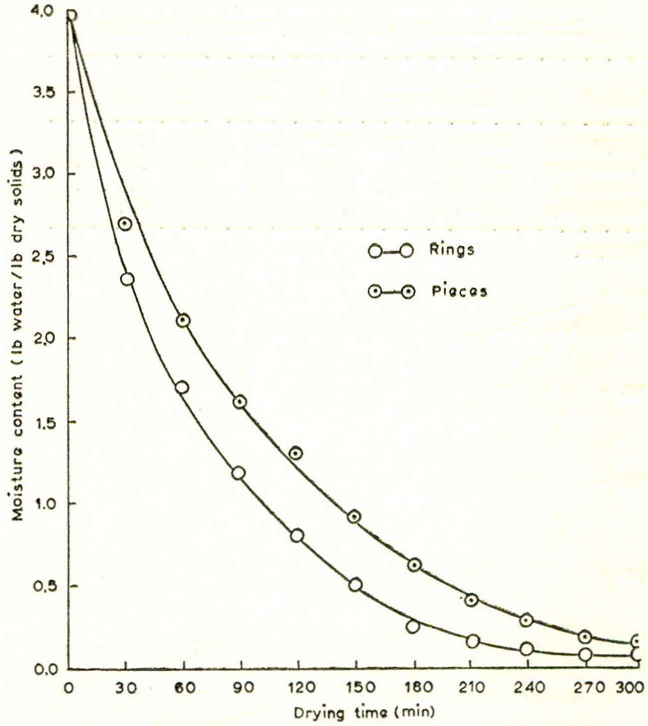

Fig. 1. Drying rate curves of rings and pieces,

Rehydration Ratios. Rings were found to have higher water absorption capacity as compared to the pieces (Table 2). This was obviously due to the difference in size and shape of the samples. A gradual but insignificant decrease in R. R. values was observed during 240-day storage in both the samples. However, rings maintained their superior rehydration characteristics as compared to the pieces throughout the storage period of dehydrated product (Table 2).

Sulphur Dioxide Content

Effect of Sample Preparation and Method of Sulphiting. Rings contained higher amount of sulphur dioxide as compared to the pieces (Table 3). This again appears to be due to the differences in size and shape of the samples. Method of sulphiting did not show significant differences in case of pieces. However, it was interesting to note that liquid sulphited rings contained higher amount of sulphur dioxide content as compared to the sulphur house-treated rings (Table 3).

Effect of Storage Time. Maximum loss of sulphur dioxide in all the four samples was observed after 60-day storage. Although sulphur dioxide continued to decrease until the termination of storage, yet at a diminished rate (Fig. 2).

TABLE 3. EFFECT OF METHOD OF PREPARATION, VARIOUS SULPHITING TREATMENTS AND STORAGE TIME ON SULPHUR DIOXIDE CONTENT OF DEHYDRATED BHES

Sample	Method of Sulphiting	Storage time (days) 0	60	120	180	240
Rings (A_1)	Sulphur house	680*	576	535	515	505
Rings (A_2)	Liquid dip	720	650	600	582	566
Pieces (B_1)	Sulphur house	504	472	438	392	375
Pieces (B_2)	Liquid dip	500	487	441	403	381

*p.p.m.

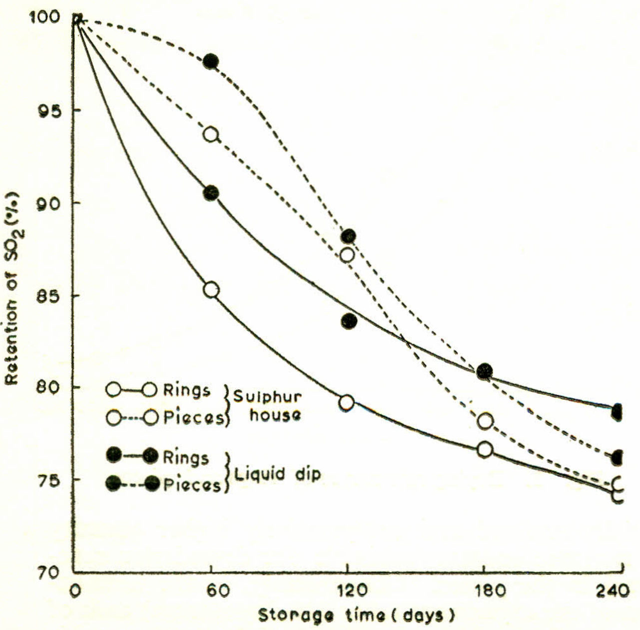

Fig 2. Effect of storage time on percent retention of sulphur dioxide content in dehydrated Bhes.'

TABLE 4. EFFECT OF METHOD OF PREPARATION, VARIOUS SULPHITING TREATMENT AND STORAGE TIME ON SUBJECTIVE EVALUATION OF DEHYDRATED BHES.

Variable tested	0				60				120				180				240			
	Sample	Total rank	Mean* rank	Rank order	Sample	Total rank	Mean* rank	Rank order	Sample	Total rank	Mean* rank	Rank order	Sample	Total rank	Mean* rank	Rank order	Sample	Total rank	Mean* rank	Rank order
Colour	A_1	7	1.4	1	A_1	7	1.4	1	A_1	7	1.4	1	A_1	7	1.4	1	A_1	7	1.4	1
	B_1	8	1.6	2	B_1	8	1.6	2	B_1	8	1.6	2	B_1	8	1.6	2	B_1	8	1.6	2
	B_2	20	4.0	3	A_2	19	3.8	3	A_2	21	4.2	3	A_2	20	4.0	3	B_2	19	3.8	3
	B_3	22	4.4	4	A_3	22	4.4	4	B_3	22	4.4	4	B_2	21	4.2	4	A_2	22	4.4	4
	A_2	23	4.6	5	B_2	24	4.8	5	B_2	23	4.6	5	A_3	24	4.8	5	A_3	24	4.8	5
	A_3	25	5.0	6	B_3	25	5.0	6	A_3	24	4.8	6	B_3	25	5.0	6	B_3	25	5.0	6
Flavour	A_3	7	1.4	1	A_3	7	1.4	1	A_2	8	1.6	1	A_3	10	2.0	1	A_3	9	1.8	1
	A_2	8	1.6	2	A_2	9	1.8	2	A_3	11	2.2	2	A_2	12	2.4	2	A_2	11	2.2	2
	B_2	17	3.4	3	B_3	16	3.2	3	B_3	15	3.0	3	B_2	13	2.6	3	B_2	14	2.8	3
	B_3	18	3.6	4	B_2	18	3.6	4	B_2	16	3.2	4	B_3	15	3.0	4	B_3	16	3.2	4
	B_1	27	5.4	5	A_1	27	5.4	5	A_1	27	5.4	5	B_1	27	5.4	5	A_1	26	5.2	5
	A_1	28	5.6	6	B_1	28	5.6	6	B_1	28	5.6	6	A_1	28	5.6	6	B_1	29	5.8	6

*Average of 5 judgements.

Subjective Evaluation of Dehydrated Bhes

Colour Evaluations. (a) Effect of Method of Sample Preparation. Sample A_1 ranked first followed by sample B_1, (Table 4) while A_3 was evaluated to be the poorest of the whole lot. This indicates that the method of sample preparation did not cause difference in the subjective quality of the dehydrated Bhes.

(b) Effect of Method of Sulphur Treatment: Sulphur house treated samples, irrespective of their size and shape, were evaluated to be better in colour as compared to either liquid sulphited or control samples (Table 4).

(c) Effect of Storage Time: Rank order of the samples did not change with the advancement of storage period, except minor variations in the 5th and 6th positions. However, untreated (control) samples were poor in colour, irrespective of the size and shape of the Bhes (Table 4).

Flavour Evaluations. Method of sample preparation; Sulphiting treatment or storage time did not show marked changes in the rank order of various samples of dehydrated Bhes as far as flavour of the product was concerned. Although A_2 and A_3 ranked better as compared to the rest of the samples, yet this was not due to the method of sample preparation or sulphiting treatment as the sample A_1 had been ranked low throughout the storage observations (Table 4). This indicates that the samples sulphited by dipping into the sulphiting solution have better flavour than sulphur house-treated Bhes. Sample B_2 may be regarded as an acceptable product as far as colour and flavour of the Bhes awere concerned. It was difficult to locate any difference, in appearance, as all the samples had a uniform appearance.

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