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Rehydration properties of freeze and tray dried button mushrooms (*Agaricus bisporus*)

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Abstract
The study was conducted to determine the rehydration properties of Freeze cum Tray dried button mushrooms. The effect of different pretreatments on dehydration characteristics was studied. The mushrooms were pre-treated with Potassium metabisulphite, Calcium Chloride and Paracetic acid respectively (T_1, T_2 & T_3). Button mushrooms were dried by freeze drying at -20 °C for 3 h and then dried in tray dryer at 70-85 °C for 6 h. After dehydration, dried mushroom slices were analyzed for rehydration ratio, rehydration of co-efficient, vitamin C, non-enzymatic browning, moisture content and sensory evaluation. The rehydration ratio varied from 6.0 to 6.6 while Vitamin C content varied from 13.55 to 24.54 mg/100 g dry matter. Effect of pre-treatments varied the yield, colour and overall acceptability score varied from 5 to 7.4 and 5.12 to 6.8 respectively. Analysis of Varience was carried out and also the effects of pre-treatments on rehydration ratio, vitamin C content and yield of final product were analysed at 5% level of significance. The optimization of dehydration process was done on the basis of rehydration ratio, colour and overall acceptability. The sample T_3 was found to be superior. The product had rehydration ratio of 6.6 and had sensory score got score 7.4 and 6.8 for colour and overall acceptability.

Keywords: Button mushroom, dehydration, freeze drying, paracetic acid, rehydration ratio, vitamin C

1. Introduction
Button mushrooms (*Agaricus bisporus*) are devoured by mankind for their characteristic aroma, texture and nutritional values. It is the most common edible cultivated mushroom species worldwide and is highly popular within consumers for its nutritional, organoleptic and medicinal properties. The quality of button mushrooms is determined by color, texture, cleanliness and flavor of which color is first perceived by consumers.

Post-harvest losses are very high in most of the horticultural commodities and it may be one of the highest in mushrooms. Mushrooms even after harvesting continue to grow, respire, mature and senesce resulting in weight loss, veil-opening, browning, wilting and finally in spoilage. Two most common post-harvest practices and aspects of mushrooms are: proper packaging and storage for the fresh mushrooms; and processing for long-term storage as well as value addition. Market for the fresh commodities is likely to continue; reverse trend has already started in the countries where processed products were being consumed. There most important of all, it is the proper packaging and storage of the fresh mushrooms which should receive the attention of all the players in the field researchers, growers and traders. Besides canning, drying, steeping and pickling currently resorted to for the long-term storage and trade; it is the production and consumption of the readymade or ready-to-make value-added mushroom products which have, of late, been receiving the attention of the mushroom research and industry. Mushroom-based soup powder, noodles and biscuits are already on the shelves. Technologies for ready-to-make mushroom pizza, mushroom curry in retortable pouches, nuggets, ketchup etc., have been developed.

Browning is one of the main causes of quality losses in mushrooms**.** Browning decreases the commercial value and generally the whitest mushrooms fetches highest price. Mushrooms are excellence source of vitamins such as B-complex and Vitamin C. It contain appreciable amount of niacin, pantothenic acid and biotin. The Nutrition facts of Freeze dried Button Mushrooms (per 100 g) is given in Table 1

Table 1: Nutrition facts of Freeze dried Button Mushrooms on dry basis

Nutrients	per 100 g edible
Energy (Calories)	293.76
Total Fat	3.88 g
Carbohydrates	17.39 g
Dietary Fiber	14.10 g
Sugars	16.45 g
Protein	34.08 g
Thaimin-B1	1.06 mg
Riboflavin	4.98 mg
Niacin	47.47 mg
Vitamin B-6	1.20 mg
Vitamin C	27.03 mg
Calcium	58.75 mg
Iron	12.22 mg
Phosphorus	1222.03 mg
Potassium	4347.61 mg

***Source*:** USDA (2017)

Though the dehydration is well-established technique for button mushroom, the mushrooms are to be dried to prepare mushroom powder for preparation or value-added products. Like dehydrated vegetables, the dehydrated mushrooms can also be rehydrated in hot water and used further in various recipes. In addition, dehydrated product, apart from increased shelf life, offers the advantage of decreased weight, which has the potential for savings in the cost of packaging, handling and transporting the product to the distant places. The quality of the rehydrated products is expressed in terms of rehydration ratio, texture, color and flavor, since the human relation to food is defined by its appearance, feel in the mouth, taste and odor. This study was conducted to generate information on suitability of drying methods, rehydration characteristic, as the information pertaining to the rehydration is limited. These rehydration characteristics play a vital role for the acceptance and use of dehydrated button mushrooms.

2. Materials and Methods

The description of various materials and methods to accomplish the experimental work to attain the desired objectives of the study entitled "Rehydration study of dehydrated button mushrooms" in different treatments are explained. The experiment was carried out during Jan to Jun 2021 in Flex Foods Ltd. Dehradun, Uttarakhand.

2.1 Process of flow sheet

Good quality (Matured with unopened cap, uniform size) of button mushrooms grown in the farm were collected, sorted and used for the study.They were sliced and pre-treated with different chemicals.

The pretreated slices were frozen at -15 ^{0}C in a Tunnel freezer. When the final moisture content reached 22% (wb), the product was transferred to cabinet tray drier and dried at 85 ^{0}C for 6 h. These dehydrated mushrooms was packed in polyethylene bag and stored at room temperature (25 to 30 ^{0}C).

The button mushrooms were dipped at different time, temperature combination for rehydration studies. Process of Freeze cum Tray Drying of Button Mushroom is shown in Fig. 1

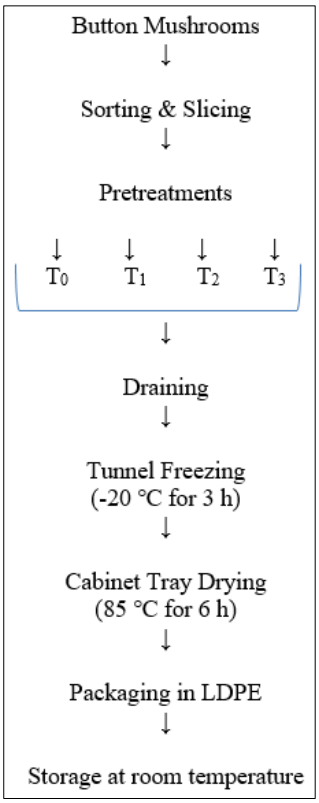

Fig 1: Freeze cum Tray Drying of Button Mushroom

3. Results and Discussion

3.1 Dehydration of Pre-Treated Button Mushrooms

3.1.1 Pre-treatment of button mushrooms

The button mushrooms were pre-treated by different chemical proportions as given in Table 2 for a period of 5 min dipping. The best colour was obtained from T_3 at 100 ppm of Paracetic acid and also T_2 at 0.3% of $CaCl_2$ and T_3 at 0.5% of KMS by visual observation. Similar result was obtained by Kumar *et al.*, (2013) for pre-treatment of button mushrooms.

Table 2: Different chemical pre-treatments for button mushrooms

Chemicals	T_0	T_1	T_2	T_3
KMS (%)	0	0.1	0.3	0.5
$CaCl_{2\,(\%)}$	0	0.1	0.3	0.4
Paracetic Acid (ppm)	0	50	70	100

3.1.2 Freeze drying of pre-treated Button Mushrooms

The freeze drying of pre-treated button mushroom is given in Table 3. The Pretreated button mushrooms were dried at freeze dryer at a temperature of -15 ^{0}C for 3 h till the final moisture content reached at 22%. Similar result was obtained by Benseddik *et al.*, (2019) [3] for apple slices.

Table 3: Freeze drying of pre-treated button mushrooms

Temperature (^{O}C)	Time (min)	Pressure (Pa)	Moisture % (wb)
25	0	0	94
-5	60	12	70
-15	120	15	45
-15	210	15	22

3.1.3 Cabinet Drying of Freeze Dried Button Mushrooms

Effect of various time and temperature for drying of freeze dried button mushrooms in cabinet dryer is given in Table 4.

The freeze dried button mushroom were dried at cabinet dryer at a temperature of 85 ^{0}C for 6 hours at 15 Pa till the final moisture content reached at 5-6%. The time and temperature combination in cabinet dryer along with pressure is tabulated in 4.

Table 4: Time and temperature for drying of freeze dried button mushrooms

Temperature (^{0}C)	Time (min)	Pressure (psi)	Moisture Content %
-20	0	0	22
40	120	8	17
85	240	15	10
25	360	0	5

3.2 Rehydration Property of Dehydrated Mushrooms

3.2.1 Rehydration of Dehydrated Button Mushrooms

The dehydrated button mushrooms were rehydrated at different time and temperature combination as given in Table 5. The rehydration ratio for control sample T_0 was good at 30 ^{0}C at 30 min of steeping whereas for T_1, the better sample was obtained from 15 min for 45 ^{0}C. For T_2 the better one was from 10 min for 60 ^{0}C and for T_3 it was for 5 min for 75 ^{0}C. The sample T_3 was good with respect to rehydration ratio and colour.

Table 5: Time -Temperature during Rehydration Process

Treatments	Batch No.	Weight of Sample	Temp. of Water (^{0}C)	Time (min.) Dip in water
T_0	1	5	30	2
	2	5	30	5
	3	5	30	10
	4	5	30	15
	5	5	30	30
T_1	1	5	45	2
	2	5	45	5
	3	5	45	10
	4	5	45	15
	5	5	45	30
T_2	1	5	60	2
	2	5	60	5
	3	5	60	10
	4	5	60	15
	5	5	60	30
T_3	1	5	75	2
	2	**5**	**75**	**5**
	3	5	75	10
	4	5	75	15
	5	5	75	30

From the Table 5, it is evident that, based on rehydration ratio, the sample obtained from 75°C for 5 min showed the best quality as well as overall acceptability of 9 point hedonic scale of rehydrated mushrooms. Similar results were reported by Arumuganathan (2015) [1].

3.2.2 Rehydration Ratio (RR)

The rehydration ratio was found to vary between 6.1 and 6.6 for different drying pre-treatments used for drying. The rehydration ratio was found to be 1:6.6, 1:6.2 and 1:6.3 for Paracetic acid, KMS and $CaCl_2$ respectively. The fresh (without) any pre-treatment of rehydrated mushroom depicted unacceptable colour. The highest rehydration ratio was however, recorded for the T_3 and lowest for control. It was also found that pre-treatment adversely affected the rehydration ration of mushrooms. It was also observed that Rehydration Ratio value decreased considerably with storage period, irrespective of the pre-treatment and drying methods.

3.2.3 Rehydration coefficient (RC)

The rehydration coefficient of mushroom treated in different pre-treatments is given in Table 6. The rehydration coefficient of the rehydrated mushroom was found of the range of 0.332 to 0.410. The maximum rehydration coefficient was found of pre-treatment of Paracetic acid followed by KMS and $CaCl_2$ for T_1, T_2 and T_3 respectively. The coefficient of rehydration ratio was found that 0.410 for Paracetic acid.
The highest rehydration coefficient was 0.410 and lowest for 0.359 for treated with Paracetic acid and fresh sample respectively. Similar observation was made by (Feng., *et al* 2021) [12]. It was observed that freeze dried product showed highest rehydration coefficient.

Table 6: Rehydration coefficient of mushroom treated in different pre-treatments

Pre-treatments	Rehydration Coefficient
Fresh	0.359
KMS	0.343
$CaCl_2$	0.388
Paracetic Acid	0.410

Rehydration coefficients improved by drying at lower system pressure as indicated by higher values of rehydration ratio. Similar results were reported by Durance and Wang (2002) [10]. The statistical analysis showed no significant effect of pre-treatment in RC of rehydrated mushrooms at 5% level of significance.

3.3 Keeping Quality of Dehydrated Button Mushrooms

In the present investigation, among the all pre-treatments (T_0, T_1, T_2 and T_3), Fresh, KMS, $CaCl_2$ and Paracetic acid respectively, the 5 minute dip treatment was found to be effective. The fresh mushrooms or without any pre-treatment deteriorated soon. The dehydrated button mushrooms obtained by pretreatments with Paracetic acid was found most acceptable.

3.3.1 Vitamin C (ascorbic acid) content of the dried mushroom

The Vitamin C content in the rehydrated sample is given in Table 7. The dehydrated button mushrooms were analyzed for Vitamin C content the values 13.55, 19.45, 20.05 and 24.54 were obtained for T_0, T_1, T_2, T_3 and T_4 respectively. The result showed that highest Vitamin C Content was 24.54 mg/100 g of. The Vitamin C content decreased for fresh sample (without pre-treatment) of dehydrated mushrooms.

Table 7: Vitamin C content in the rehydrated sample

Pre-treatments	Vitamin C (mg/100 g dry matter)
Fresh	13.55
KMS	19.45
$CaCl_2$	20.05
Paracetic acid	24.54

The result showed that sample of Paracetic acid retained the maximum of ascorbic acid followed by KMS, $CaCl_2$, and Fresh sample. It was due to the fact that the Paracetic acid treatment prevented the ascorbic acid from oxidation. The

higher retention was due to the application of Paracetic acid treatment and lower due to no treatments.

4.3.2 Non-Enzymatic Browning of the Dried Mushroom

Non-enzymatic browning in the rehydrated sample is given in Table 8. The Non-enzymatic browning of the mushroom were 1.30, 1.25, 0.40 and 0.25 for T_0, T_1, T_2 and T_3 respectively. The value of OD (Optical Density) ranged from minimum of 0.25 to maximum of 1.30. The maximum value obtained incase of fresh sample 1.30 followed by KMS, $CaCl_2$ and Paracetic acid. The lower OD in the sample other than fresh was due to the pre-treatments *viz*. Paracetic acid. The fresh samples had suffered from enzymatic and non-enzymatic browning due to lack of any pretreatments. Thus, from point of view browning which it was indicative of color of the dried mushroom. The best mushroom process would be to dry the mushroom pieces after treatment of Paracetic acid.

Table 8: Non-enzymatic browning in the rehydrated sample

Pre-treatments	OD
Fresh	1.30
$CaCl_2$	1.25
KMS	0.40
Paracetic Acid	0.25

Sethi *et al.,* (1999) advocated the range of 0.083 to 1.656 in case of *Agaricus bisporus* which supports the result of present work. Saguna *et al.,* (1995) report the range of 0.1 to 0.35 in case of oyster mushroom while using air temperature of 60-70 ^{0}C. Lidhoo and Agrawal (2008) suggested the OD of 0.162 as average for *Agaricus bisporus*.

3.3.3 Sensory Evaluation of the rehydrated mushrooms

The sensory evaluation of the rehydrated sample is given in Table 9. The sensory evaluations of rehydrated mushrooms were analyzed by 9 point hedonic scale. Table 9 shows that T_0, T_1, T_2 and T_3 denotes non-treated, KMS, $CaCl_2$, and Paracetic acid mushroom after dehydration respectively. The result found that highest score of 9 point hedonic scale of pre-treated with Paracetic acid followed by KMS, $CaCl_2$ and Fresh sample. And also result found that colour rehydrated mushrooms were best for Paracetic acid of 100 ppm.

The Table 9 explains the different test between various pretreatments. The lowest point was get of non-treated sample of rehydrated mushroom Colour, Flavor, Taste, Appearance and Overall acceptability for 5, 4.1 4.1, 5.2 and 5.1 respectively. The highest point was get in treated with Paracetic Acid, Colour, Flavor, Taste, Appearance and Overall acceptability for 7.4, 6.5, 6.6, 7.0 and 6.8 respectively.

It observed that the mean score for various sensory attributes of mushroom dried under different pretreatments varied from 4.1 to 7.8 out of the highest possible mean score of 9 indicating that the pretreatment created variability in the dried product. The mean sensory score in this finding was in accordance with that Lidhoo and Agrawal, 2008 who reported the mean score of 4.3 to 7.8 in case of mushroom dehydration.

Table 9: Sensory Evaluation of the Rehydrated Mushroom

Treatment	Colour	Flavour	Taste	Appearance	Overall
T_0	5	4.1	4.2	5.1	5.1
T_1	7.2	6.2	6.8	7	6.7
T_2	6.4	5.6	4.9	5.8	5.8
T_3	7.4	6.5	6.6	7	6.8

4. Conclusion

Button mushrooms were pretreated with 100 ppm Paracetic acid. Dehydration of pretreated button mushrooms with help of Tunnel freezer at -15^{o}C for 3 h and Cabinet tray dryer at 85^{o}C for 6 h. Analyzed rehydration properties like rehydration ratio, rehydration coefficient and keeping qualities of dehydrated button mushrooms.

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