Int.J.Curr.Microbiol.App.Sci (2020) Special Issue-11: 761-773

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 Special Issue-11 pp. 761-773
Journal homepage: http://www.ijcmas.com

Original Research Article

Effect of Temperature and Pretreatment on Drying Characteristics of Onion

Anuj Yadav*

Swami Vivekanand Subharti University (Meerut), India

**Corresponding author*

Keywords

Dehydration, colour, Pungency, RBG, Rehydration ratio

A B S T R A C T

The present study was carried out to investigate the drying kinetics of onion slices during tray drying and the effects of process parameters during tray drying such as pretreatment and temperature of drying on drying kinetics, colour, pungency and rehydration ratio were studied. The drying rate increased with increase of temperature and drying time but time required in drying at temperature range of untreated onion slices at 50°C, 60°C and 70°C, are 330,270 and 210 min respectively. Treated onion slices at 50°C, 60°C, and 70°C, are 240,210 and 160 min respectively. It showed that time decreases with the increase of temperature and treated sample took less time in drying. And Treated samples showed light colour compared to untreated sample but both sample showed colour increases with the increase of temperature. The treated samples with pyruvate content 5.46,5.32,5.02 $\mu mol/g^{-1}$ at 50°C, 60°C, and 70°C respectively showed a higher flavour content than the untreated samples (4.92, 4.87,4.75 $\mu mol/g^{-1}$ 50°C, 60°C, and 70°C respectively and showed that pyruvate content decrease with increase the temperature. Other quality parameter, Rehydration ratio observed an increase in rehydration ratio with increase in drying temperature. Quality of dried onion slice in respect to colour and rehydration was superior of treated sample at 60°C.

Introduction

Fruits and vegetables especially fresh ones, are liked by all but their availability is seasonal. Most of the fruits and vegetables are available for about three to four months every year. Dehydration techniques are used so that people can enjoy them during off season. Dehydration is the process by which moisture content are reduced to the maximum by drying process and these dehydrated varieties, when soaked in water, retain the original flavor and taste. One of the easiest ways to keep food for later use is the process of dehydration. Food preservation is the primary reason for dehydration. Dehydration of fruits and vegetables also lowers the cost of packaging, storing, and transportation by reducing both the weight and volume of the final product. Onion (*Allium cepa* L.) is an important vegetable crop in India as well as in the world. Amongst the onion producing countries in the world, India ranks second in area and production, the first being China. The highest productivity of onion in world is of Korea (67.25 MT/ha) followed by USA (53.91 MT/ha), Spain (52.06 MT/ha) and Japan (47.55 MT/ha). India being a second major onion producing country in the world has a productivity of 10.16 MT/ha only (FAO, 2008). Onions have many uses as folk remedies and recent reports suggest that onion plays a part in preventing heart disease and other ailments (Augusti, 1976).

Onion (*Allium cepa* L.) is an important vegetable crop in India as well as in the world. Amongst the onion producing countries in the world, India ranks second in area and production, the first being China. Both fresh market and dehydrated onions (largely granulated and powdered) appear in a wide variety of canned and frozen products. Common onions are normally available in three colors viz. yellow, red, and white. Yellow onions are full-flavored and are reliable stand by for cooking almost anything. Yellow onions turn a rich, dark brown when cooked and give french onion soup its tangy sweet flavor. The red onion is a good choice for fresh uses or in grilling and char-broiling. White onions are the traditional onion used in classic Mexican cuisine. They have a golden color and sweet flavor when sautéed. While the large mature onion bulb is the onion most often eaten, onions can be eaten at immature stages. The onions are generally dried by air drying methods. But the dried onions do not retain much amount of ascorbic acid and also lose colour and flavor. In mechanical drying, loss of ascorbic acid is 71.90% and browning index is 61 at 420 nm. Generally, tray drying or tunnel drying methods of air drying are used for drying of the fruits and vegetables dehydration. These are time consuming methods. As dehydrated onions are finally consumed in broken form or are converted into powder form, fluidized bed drying seems to be suitable for drying of dehydrated onions.

It was expected that the outcome of the research work would be directly useful to the dehydration plant for getting good quality dehydrated onion flakes. Also, it could be possible to suggest the optimum drying condition thereby increased production capacity as well as reduction in energy consumption. Moreover, the information generated would be highly useful to the researcher as well as designers of mechanical dehydration unit.

Materials and Methods

The experiments were conducted at the Process and Food Engineering Laboratory of the Department of Agricultural Engineering and Food Technology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut Fresh, good quality onion (*Alliium cepa L.)* were procured from the local market in bulk for the whole set of experiments. Care was taken to select fresh, medium size and without any defect on visual inspection. The onion, after peeling, washing and removal of surface water cut into slices of thickness 5mm each. The average moisture content of fresh onion was determined by hot air drying method at 110^{o}C, was found to be 86% on wet basis. Fresh onion slices were pretreated with 0.5% potassium meta bisulphite for 10 minutes. Now, untreated and treated onion slices were dried at 50^{0}C, 60^{0}C and 70^{0}C at no load condition in tray dryer. Drying was continued up to the moisture content of 5-6 % d.b.

Measurement of variables

Different methods were used for measurement different variables described below.

Initial moisture content

Initial moisture content of onion samples were determined by hot air oven drying method as recommended by Ranganna (2001).

$$IMC = \frac{M_1 - M_2}{M_0} \times 100 \quad \text{..... (1.1)}$$

Where,

IMC = Initial moisture content of sample, % (w.b.)

M_0 = Initial weight of sample taken, 5 g

M_1 = Weight of sample before oven drying plus weight of dish with cover, g
M = Weight of dried and desiccated sample plus weight of dish with cover, g.

Moisture content during drying experiment

Moisture content of the samples during drying was computed through mass balance. For this purpose, weight of the samples during drying was recorded at predetermined time interval. The following formulae were used to calculate the moisture content.

$$MC = \frac{W - W_{d'}}{W_{d'}} \times 100 \quad .....(1.2)$$

Where,
M.C. = Moisture content, % (d.b.)
W = Weight of sample at any time, g
W_d' = Weight of bone dry material, g

Weight of bone dry material was calculated as

$$W_{d'} = W_i \left(\frac{100 - mc'}{100}\right) \quad .....(1.3)$$

Where,
W_i = Initial weight of sample, g
mc′ = Moisture content of sample, % (w.b.).

Equilibrium moisture content

Equilibrium Moisture Content was required for calculations of moisture ratio (MR). It was determined using a method developed by (Henderson and Perry, 1976) in which last three moisture content readings of drying experiment were considered. Following equation was used to determine the equilibrium moisture content.

$$\text{EMC (\% d.b.)} = \frac{M_1 \times M_3 - (M_2)^2}{M_1 + M_3 - 2M_2} \quad ...... (1.4)$$

Where,
M_1 = Moisture Content (%db) at time t_1
M_2 = Moisture Content (%db) at time t_2
M_3 = Moisture Content (%db) at time t_3
Moisture content should be considered with the following condition
$(t_3 - t_2) = (t_2 - t_1)$.

Moisture ratio and drying rate

Moisture Ratio (MR) is defined as follows

$$MR = \frac{M - Me}{Mo - Me} \quad ... (1.5)$$

Where,
M = Moisture content, % (d. b.) at time t (min.) during drying.
Mo = Moisture content, % (d. b.) at the initiation of drying i.e. at zero time.
Me = Equilibrium moisture content, % (d. b.).

Drying Rate is defined as,

$$\frac{dm}{dt} = \frac{M_2 - M_1}{\Delta t} \quad ...... (1.6)$$

Where,
Δt = difference in time.
Moisture ratio and drying rate at different time intervals were calculated by using equation 3.5 and 3.6 to study the drying characteristics of onion slices.

Determination of quality parameters

Determination of colour

The colour of samples was measured by using IMAGE J (java based software). RGB colour space is an additive colour system based on tri-chromatic theory. It is found in systems that use a CRT to display images. RGB is easy to implement but non–linear with visual perception. It is device-dependent and specification of colors is semi–intuitive. RGB is very commonly, used in virtually every computer system as well as television, video etc. RGB is the color space produced on a CRT (or similar) display when pixel values are applied to a graphics card. RGB space may be visualized as a cube with the three axes corresponding to red, green and blue. The bottom corner, where red = green = blue = 0, is black, while the opposite top corner, where red = green = blue = 255 (for an 8 bit per channel display system), is white.

In case of color image, in the RGB color space, every individual color component, namely Red, Green and Blue has its histogram. Then, the percentage composition of every individual color component are to be evaluated. Using this percentage composition the level for a component can be set as a standard in classifying the dried onion based on a particular color orientation. Then the Image J software was used for the measuring the values of red, green and blue. Fig. 1 shows computer representation of R G B values in Image J software. Table 1 illustates the representation of different RGB values as given below.

Determination of pungency

Pungency in onion is derived from a number of volatile sulphur compounds. These compounds are produced when the onion cell is mechanically disrupted, bringing the enzyme allinase in contact with the flavour precursors S-alkyl l-cysteine sulphonides. The amount of pyruvic acid generated enzymatically upon onion homogenization is thus a good measure of the action of allinase on the flavor precursors and has been shown to be correlated with perceived onion pungency. Pyruvate analysis was performed according to (Schwimmer and Weston, 2003) with modifications. 20 g of onion sample were taken into 60 ml of 5% trichloroacetic acid to inactivate the allinase enzyme for background measurement of pyruvate levels. After 1 hour, controls were blended for 3 min and filtered. Control filtrates were diluted (1:10) with distilled water and analyzed for pyruvate. Sample wedges were blended with an equal volume of distilled water for 3 min, allowed to sit covered for 15 min, filtered, and diluted in distilled water (1:20). Each reaction test tube contained 1 ml of diluted filtrate, 1 ml of distilled water, and 1 ml of 2,4-dinitrophenylhydrazine (0.0125% DNPH in 2 N HCl). A blank was prepared with 2 ml water and 1 ml DNPH. All reaction tubes were vortexed and placed in a water bath at 37°C temperature for 10 min. After the incubation period, 5 ml of 0.6 N, NaOH was added, and test tubes were vortexed and let stand for 5 min. Pyruvate content was measured using a spectrophotometer at 420 nm for both control and sample filtrates. Standards were prepared with sodium pyruvate. Final pyruvate concentration per bulb (micromoles per grams fresh weight) was calculated from the difference between pyruvate levels in the sample.

Rehydration ratio

According to Ranganna (1986), there is no standard time for rehydration of fruits and vegetables. It varies from product to product. Rehydration time should be standardized through trial runs (Kar, 1998).

$$\text{Rehydration ratio (RR)} = \frac{WR}{WD} \quad (1.7)$$

Where,
WR = weight of rehydrated onions, g.
WD = weight of dehydrated onions, g.

Statistical analysis

The experimental drying data were graphically analyzed in terms of moisture loss, and solid gain with drying time. The experimental data was statistically and graphically analyzed with the help of analysis of variance (ANOVA) and spread sheet (EXCEL) software packages on personal computer. Significance was defined at $P \leq 0.5$.

Result and Discussion

Drying

Equilibrium moisture content

The moisture loss data were first analyzed for equilibrium moisture content using Henderson and Perry method (Henderson and Perry, 1976). The estimated equilibrium moisture content is varied between 1.15 to 6.78%. It can be observed that the equilibrium moisture content for untreated samples was higher than that of treated samples.

Dehydration characteristics

The experimental data of dehydrated onion slices in relation to moisture content and drying time are given in Table 4.1 to 4.8. The drying curves of moisture content verses time are showed in Fig. 2 to 3. From the figures, it was observed that the rate of drying is lower at lower temperature and drying rate increased with the increasing of temperature.

With drying, the time taken to reduce the initial moisture content of untreated sample (820%) and treated sample (930%) to the final moisture content 5-6% varies between 210-610 min for untreated and 160-480 min for treated sample.

Effect of temperature and pretreatment on moisture content

Initial moisture content of untreated samples at 50°C, 60°C and 70°C reduced from 855.70 to 5.91%, 863.22 (4.18%) and 872.79 (5.67 %) on (db) in 330, 270, 210 min respectively and drying rate varied from 8.90, to 0.20. Fig. 2 shows the drying curve of untreated samples at 50°C, 60°C and 70°C.

Initial moisture content of treated samples at 50°C, 60°C and 70°C reduced from 1160 (5.85%), 975.79 to 5.12% and 907.92 to 5.90 % (db) in 240, 210,160 min respectively and drying rate varied from 11.9 to 0.50. Fig. 3 shows the drying curve of treated samples at 50°C, 60°C and 70°C.

The two way ANOVA for percentage moisture content at 40°C, 50°C, 60°C temperature for untreated and treated onion sample was performed. The results revealed that pretreatment had significant effect on percentage water loss where the values of moisture content in f calculated value at 5 per cent significant level was satisfactory. The ANOVA results are shown in Table 3–0 and 7-9. The S mark indicates the satisfactory process condition at 5% probability level and the NS mark indicates the non-satisfactory condition at 5% probability level whereas the blank indicates the unacceptable process. In these tables the value of time in F calculated value at 5 per cent significant level is 2.59 for untreated and for pretreated, which is satisfactory.

Effect of temperature and pretreatment on quality parameters

The effect of drying air temperature for both treated and untreated onion slices were measured in terms of colour, pungency and rehydration ratio. It shows the effect of air temperature and pretreatment on quality parameters of onion slices.

Effect on color

The colour was measured in terms of red, green and blue (RGB) values of dehydrated onion slices. Lower histogram (RGB) value indicated darker colour. The average red, green and blue (RGB) values of fresh control onion slices and treated onion slices were 133.72 and 160.38 respectively as shown in Fig. 4 to 8. These values show higher RGB value which indicated light (showed more white and less magenta-yellow) colour of onion slices in comparison of untreated onion slice. The average red, green and blue value of fresh and untreated onion slices were 126.69, 113.20, 108.54 at 50°C, 60°C and 70°C respectively shown in table 5 to 7. The average red, green and blue value of fresh treated and tray-dried treated onion slices were 170.28,137.70,133.61 at 50°C, 60°C and 70°C respectively in table 10 to 17. It was observed that there was a gradually decrease in RBG value of treated onion slices. The treated sample showed less colour development due to sulfite treatment. Thus the colour values can be minimized by involving sulfite treatment. Similar results were also reported by Mitra *et al.*, (2011)

Effect of temperature and pretreatment on pungency in terms of pyruvate content

The pyruvate values of untreated onion slices were found to be 4.92, 4.87 and 4.75 $\mu molg^{-1}$ at 50°C, 60°C and 70°C respectively. It showed that pyruvate content values decreased with increase in temperature. Treated onion sample slices showed 5.46, 5.32 and 5.02 $\mu molg^{-1}$ pyruvate content at 50°C,60°C and 70°C respectively, because elevated temperature again causes more liberation of sulphur compound and thus at 70°C, the pyruvate content was found to be lower showed in Table 12 . Thus it can be concluded that the amount of liberation of sulphur compounds of onion depends upon temperature. It is evident that the flavour content can be maximized by involving the sulfite treatment and adopting a lower drying temperature. Similar result was reported by Mitra *et al*., (2011).

Effect of temperature and pre-treatment on rehydration ratio

Value of rehydration ratio of untreated sample is 5.33, 5.51 and 5.66 at 50°C, 60°C and 70°C respectively. Value of RR of treated sample is 5.99, 5.07 and 5.48 at 50°C, 60°C and 70°C respectively as explicated in Table 13 Rehydration efficiency was better at a higher temperature because of faster drying at higher temperature. Thus, the RR can be maximized by drying the untreated samples at higher temperature. El-Mesery (2012) also observed an increase in rehydration ratio with increase in drying air temperature.

In conclusion, drying and the qualitative parameter colour pungency and rehydration ratio of treated sample were found very good in comparison of untreated sample. Moisture content of untreated onion slices varied from 85 to 89 % (w.b.) while moisture content of treated onion slices was in the range of 92 % to 93% (w.b.). Time required in drying at temperature range of untreated onion slices at 50°C, 60°C and 70°C, were 330, 270 and 210 min respectively. Treated onion slices sample at 50°C, 60°C and 70°C, were 240, 210 and 160 min respectively. It showed that time decreases with the increase of temperature and treated sample takes less time in drying. Colour is measured in the terms of average RGB value, of untreated onion sample were 126.69, 113.20 and 108.54 at 50°C, 60°C and 70°C respectively. In treated onion slices sample average RGB value were 170.28, 137.70 and 133.61 at 50°C, 60°C, and 70°C respectively. Treated samples showed light colour compared to untreated sample. It was also observed that colour increases with the increase in temperature. Pungency value in the terms of pyruvate content of untreated sample were 4.92, 4.87,4.75 µmolg^{-1} at 50°C, 60°C, 70°C respectively. The value of pyruvate content of treated sample were 5.46,5.32,5.02 µmolg^{-1} at 50°C, 60°C and 70°C respectively. The treated samples showed a higher flavour content than the untreated samples. It was evident that the flavour content can be maximised by involving the sulfite treatment and adopting a lower drying temperature. The Value of rehydration ratio of untreated sample were 5.33, 5.51 and 5.66 at 50°C, 60°C and 70°C respectively while the rehydration value of treated sample were found 5.99, 5.07 and 5.48 at 50°C, 60°C and 70°C respectively. From the Table 12 it was revealed that an increase in rehydration ratio with increase in drying air temperature in both untreated and treated same.

Table.1 Table for evaluation of RGB value

S.No.	Label	Area	Mean	Min	Max
1	Red	24964	156.778	71	228
2	Green	24964	117.730	17	223
3	Blue	24964	126.736	32	230
4	(R+G+B)/3	24964	133.723	41	227
5	0.299R+0.587G+0.114B	24964	130.459	37	225

Table.2 Experimental data of moisture content and drying time of untreated sample of onion slices dried at 50°C 60°C and 70°C

Temperature →	50°C	60°C	70°C
Time(min) ↓	M.C(% d.b)	M.C(% d.b)	M.C(% d.b)
0	855.70	863.21	872.78
30	628.75	614.51	571.84
60	464.85	333.42	319.64
90	343.81	155.33	130.23
120	250.51	73.8	41.22
150	152.15	37.31	27.03
180	89.12	20.16	14.77
210	51.30	9.43	5.67
240	31.12	7.28	-
270	16	4.18	-
300	8.43	-	-
330	5.91	-	-

Table.3 ANOVA for drying time and moisture content of untreated tray dried onion slices at 50°C

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*	**Result**
Rows	189875.2	11	17261.38	0.237708	2.81793	S
Columns	35087.49	1	35087.49	0.483193	4.844336	S
Error	798774.4	11	72615.85			
Total	1023737	23				

Table.4 ANOVA for drying time and moisture content of untreated tray dried onion slices at 60°C

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*	**Result**
Rows	478548.1	8	59818.52	0.471251	3.438101	S
Columns	394476.3	1	394476.3	3.107691	5.317655	S
Error	1015484	8	126935.5			
Total	1888508	17				

Table.5 ANOVA for drying time and moisture content of untreated tray dried onion slices at 70°C

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*	**Result**
Rows	231039	7	33005.56	0.439489	3.787044	S
Columns	81681.64	1	81681.64	1.087639	5.591448	S
Error	525699.6	7	75099.94			
Total	838420.1	15				

Table.6 Experimental data of moisture content and drying time of treated samples of onion slices dried at 50°C 60°C and 70°C

Temperature →	**50°C**	**60°C**	**70°C**
Time(min) ↓	**M.C(% d.b)**	**M.C(% d.b)**	**M.C(% d.b)**
0	1160	972.79	907.91
30	900.53	708.88	551.12
60	698.91	526.51	373.72
90	489.74	361.30	149.96
120	310.8	172.49	22.97
150	121.78	66.58	11.76
180	36.09	26.89	5.9
210	20.97	5.12	-
240	5.85	-	-

Table.7 ANOVA for drying time and moisture content of treated tray dried onion slices at 50° C

Source of Variation	***SS***	***df***	***MS***	***F***	***F crit***	**Result**
Rows	478548.1	8	59818.52	0.471251	3.438101	S
Columns	394476.3	1	394476.3	3.107691	5.317655	S
Error	1015484	8	126935.5			
Total	1888508	17				

Table.8 ANOVA for drying time and moisture content of treated tray dried onion slices at 60°C

Source of Variation	***SS***	***df***	***MS***	***F***	***F crit***	**Result**
Rows	284076.3	7	40582.33	0.446209	3.787044	S
Columns	250145	1	250145	2.750383	5.591448	S
Error	636644.1	7	90949.15			
Total	1170865	15				

Table.9 ANOVA for drying time and moisture content of treated tray dried onion slices at 70°C

Source of Variation	***SS***	***df***	***MS***	***F***	***F crit***	**Result**
Rows	245597.5	6	40932.92	0.509112	4.283866	S
Columns	142682.7	1	142682.7	1.774649	5.987378	S
Error	482403.3	6	80400.56			
Total	870683.6	13				

Table.10 RGB value of fresh untreated onion slices

S.no.	Label	Area	Mean	Min	Max
1	Red	24964	156.778	71	228
2	Green	24964	117.730	17	223
3	Blue	24964	126.736	32	230
4	(R+G+B)/3	24964	133.723	41	227
5	0.299R+0.587G+0.114B	24964	130.459	37	225

Table.11 RGB value of untreated tray dried onion slices at 50°C.

S.no.	Label	Area	Mean	Min	Max
1	Red	23275	139.016	14	236
2	Green	23275	119.453	5	238
3	Blue	23275	121.637	9	229
4	(R+G+B)/3	23275	126.699	10	233
5	0.299R+0.587G+0.114B	23275	125.560	9	236

Table.12 RGB value of untreated tray dried onion slices at 60°C

S.no.	Label	Area	Mean	Min	Max
1	Red	25900	125.981	11	248
2	Green	25900	108.940	10	250
3	Blue	25900	90.721	0	246
4	(R+G+B)/3	25900	108.543	10	248
5	0.299R+0.587G+0.114B	25900	111.964	11	249

Table.13 RGB value of untreated tray dried onion slices at 70°C.

S.no.	Label	Area	Mean	Min	Max
1	Red	20020	132.391	27	236
2	Green	20020	106.269	7	237
3	Blue	20020	100.974	15	232
4	(R+G+B)/3	20020	113.206	23	235
5	0.299R+0.587G+0.114B	20020	113.480	21	236

Table.14 RGB value of fresh treated onion slices

S.no.	Label	Area	Mean	Min	Max
1	Red	19630	178.900	87	240
2	Green	19630	147.977	41	232
3	Blue	19630	154.304	40	238
4	(R+G+B)/3	19630	160.389	56	236
5	0.299R+0.587G+0.114B	19630	157.962	55	234

Table.15 RGB value of treated tray dried onion slices at 50°C

S.no.	Label	Area	Mean	Min	Max
1	Red	18522	171.954	91	207
2	Green	18522	172.697	76	212
3	Blue	18522	166.090	69	205
4	(R+G+B)/3	18522	170.287	79	208
5	0.299R+0.587G+0.114B	18522	171.729	80	210

Table.16 RGB value of treated tray dried onion slices at 60°C.

S.no.	Label	Area	Mean	Min	Max
1	Red	23868	163.736	57	231
2	Green	23868	120.474	8	229
3	Blue	23868	128.914	19	230
4	(R+G+B)/3	23868	137.708	30	228
5	0.299R+0.587G+0.114B	23868	134.391	26	228

Table.17 RGB value of treated tray dried onion slices at 70°C.

S.no.	Label	Area	Mean	Min	Max
1	Red	30176	148.778	14	226
2	Green	30176	123.452	4	226
3	Blue	30176	128.583	10	219
4	(R+G+B)/3	30176	133.615	11	223
5	0.299R+0.587G+0.114B	30176	131.620	9	225

Table.18 Effect of temperature on Pungency of dehydrated onion

Temp. Range (°c)	Pungency in term of pyruvate content untreated ($\mu mol/g^{-1}$)	Pungency in term of pyruvate content Treated ($\mu mol/g^{-1}$)
50	4.92	5.46
60	4.87	5.32
70	4.75	5.02

Table.19 Effect of temperature Rehyration Ratio of dehydrated onion

Exp. No.	Drying Temperature T(^{0}C)	Weight after rehydration (control (g)	Rehydration ratio (control)	Weight after rehydration (treated) (g)	Rehydration ratio (treated)
1	50	10.66	5.33	9.40	4.70
2	60	11.02	5.51	9.84	4.92
3	70	11.32	5.66	10.34	5.17

Fig.1 Representation of colour solid in terms of 'R', 'G' and 'B' values

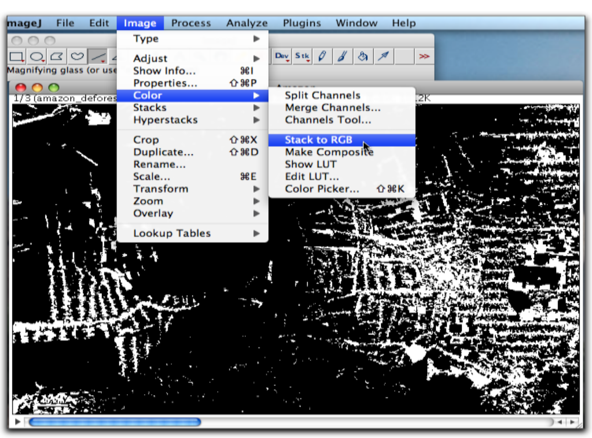


Fig.1A Representation of colour solid in terms of 'R', 'G' and 'B' values
Tables and figures

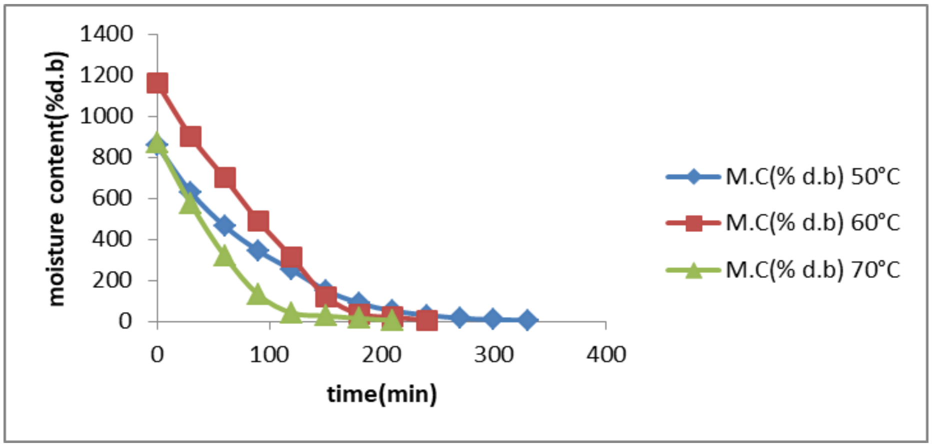


Fig.2 Comparison between moisture content and drying time of untreated sample of onion slices dried at 50°C 60°C and 70°C

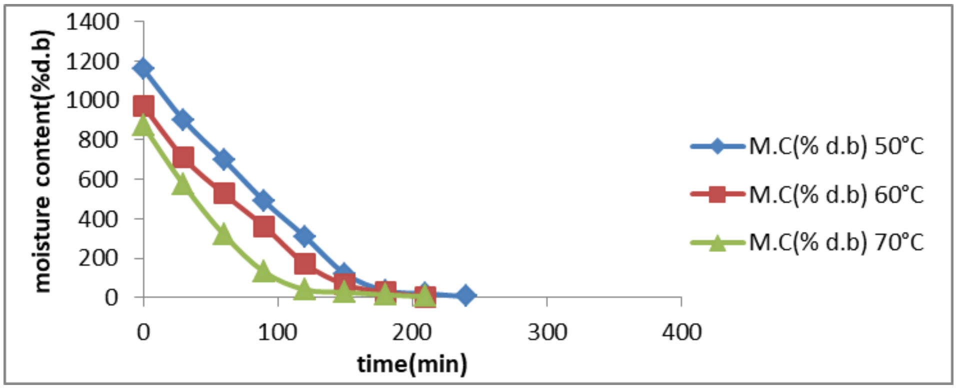


Fig.3 Pyruvate content (µmolg^{-1}) of untreated and treated onion slices at 50°C, 60°C and 70 °C

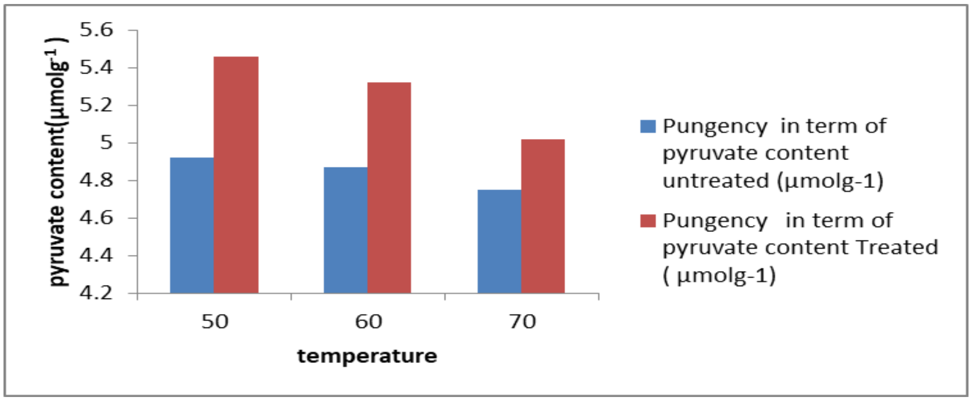
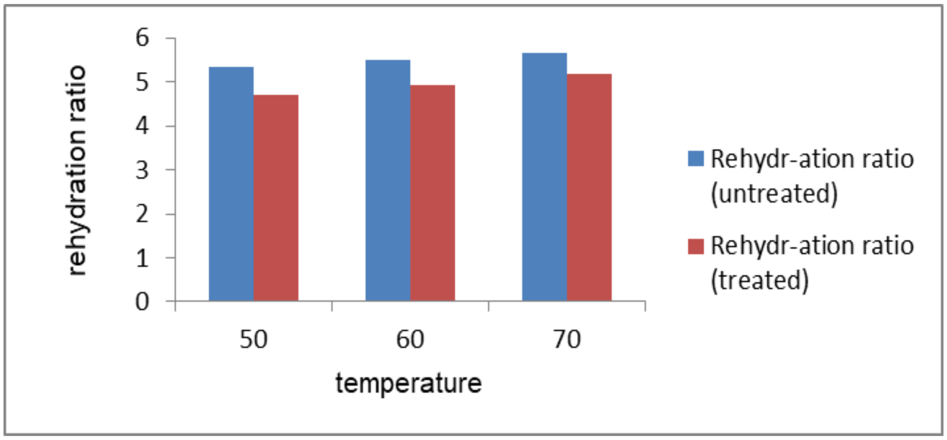


Fig.4 Rehydration ratio of untreated and treated onion sample at 50°C, 60°C and 70 °C



References

Augusti, K. T. (1996). Therapeutic values of onion and garlic. *Indian Journal of Experimental Biology*, 64, 334-336

Augusti, K.T. (1976). Gas chromatographic analysis of onion principles and study on their hypoglycaemic action. *Indian J. Experimental. Biology*. 14:110

FAO, (1980). Food and Agriculture Organization of the United Nations, Assessment .Production report -8

Henderson, S.M., Pery, S. (1976) . Grain drying theory. Temperature effect on drying coefficient. *J. Agril Engg Research*, 6 (3): 169 - 174.

Kar, A. (1998). Osmo-air dehydration characteristics of button mushroom. Thesis, M-tech. G.B. Pant University of Agriculture and Technology, Pantnagar.

Mitra, J., Shrivastava, S.L. and Rao, P. S. (2011). Process optimisation of vacuum drying of onion slices. Czech *Journal of Food Sciences; Praha*. 29: 6, 586-594.

Ranganna, S. (1986). Hand book of analysis and quality control for fruit and vegetable products. 2nd edition. Tata McGraw hill publication Co. Ltd., New Delhi. p 112.

Ranganna, S. (2001). Hand book of analysis and quality control of fruit and vegetable products. Tata McGraw Hill Pub. Co. Ltd., New Delhi.

Schwimmer, S. and Weston, W.J. (2003). Enzymatic development of pyruvic acid in onion as a measure of pungency. *Journal of Agricultural and Food Chemistry*, 99(4), 301–304.

Singh, Hardeep., Sodhi, Singh. and Navdeep. (2000). Dehydration kinetics of onion. *J. Food. Science. and Technology*. 37(5): pp 520-522.

Singh, U. (2005). Studies On High Velocity Hot Air Drying Characteristics Of Ginger (*Zingiber officinale* Roscoe) Slices. Unpublished M. Tech. Thesis, G. B. Pant University of Agriculture and Technology, Pantnagar.

Srivastav, G.K. and Sulebele, G.A. (1975). Dhydration of cauliflower – Effect of pre-treatment on rehydration characteristics. *Indian Food Packer*.7: 5-10.