

Investigation on Quality Parameters of Stored Ginger (*Zingiberofficinale*) in Different Packaging Materials by Convective-Cum-Microwave Drying Technique

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Abstract – The objective of the study was to compare the quality parameters of microwave dried ginger before and after storage. For this Convective-cum- microwave drying of ginger was carried out at three different levels of exposure time, pause time and microwave power. Moisture content decreased rapidly at the initial stage of microwave drying followed by a relatively slow decrease in the removal of moisture that was prominent at lower power and higher pause times. Higher power and more exposure time resulted in faster drying rate in the initial phase of drying. Drying period reduced with increase in the microwave power level and exposure time. Quality attributes like rehydration ratio, shrinkage ratio, colour change, oil content and overall acceptability were calculated. The dried ginger was then stored for 6 months in different packaging materials i.e. LDPE, HDPE and laminate packages. The quality parameters of the dried ginger were again calculated after the storage period was over. It was observed that there was not much variation in the quality attributes. Though the maximum variation in quality was observed in LDPE package and the results were comparable for HDPE and Laminate packages.

Keywords – Ginger, Microwave, Quality, Drying, Storage.

I. INTRODUCTION

A major goal of food processing is to convert perishable commodities into stable products that can be stored for extended periods thereby reducing losses, making them available at the time of shortage and off-season use and for places which are far away from production site. Drying is the most common way to preserve agricultural produce especially the surplus ones. During drying, the water is evaporated from the freshly harvested ginger rhizome to moisture content close to that of its storage environment (Rao 1986). Dried foods prevent deterioration as the micro-organisms which cause food spoilage and decay are unable to grow and multiply in the absence of sufficient water and many of enzymes which promote undesired changes in the chemical composition of the food cannot function without water.

Food industry is always looking for a drying method which is rapid, more uniform, energy efficient, and yielding hygienic and safe products; on that note, microwave drying has been found to be a better option as compared to conventional hot air drying (Berteli and Marsaioli Jr, 2005). Microwaves, with unique property to penetrate into food materials, cause volumetric internal heating within them (Tang *et al.*, 2002). This method of heat transfer offers many advantages and reduces the process time considerably. Application of microwave energy particularly, in drying or dehydration has been successfully

commercialized in many sectors of food industry due to considerable reduction in drying time; that has led to microbiologically-safe, better quality product (Maskan, 2001; Zhang *et al.*, 2006; Vadivambal and Jayas, 2007).

Most of the research work on combined microwave-convective drying of agricultural commodities has been reported for low-moisture foods such as grains (Mosqueda and Tabil 2011). This necessitates developing an efficient drying technique that reduces the drying time, energy consumption and produce good quality dehydrated product.

When discussing storage stability, one is concerned with the organoleptic, physical, and chemical changes that take place in the dried fruit and vegetables during storage and the rates at which these changes occur. Storage temperature is of vital importance in relation to maintenance of quality. Further, type of packaging material and the package environment are other major factors in terms of storage stability. The type of package used varies with expected storage conditions.

II. MATERIAL AND METHODS

Multilayer drying of Pretreated Ginger was carried out at an air temperature of 60° C at air velocity of 3.5 m/s and loading density of 44.66 kg/m² upto a moisture content of ≈ 35% (wb) after which drying rate reduced drastically. Further the sample was dried to ≈ 6% (db) in a microwave dryer at different exposure times 5s, 15s and 25s, pause times 10s, 55s, 100s and power levels 270W, 810 W and 1350W. Quality attributes of the dried product were determined. The experiment was designed using response surface methodology statistical techniques.

3.1. Multilayer Drying of Ginger

3.1.1. Sample Preparation

Ginger was peeled manually and then sliced within a thickness of 2.5 mm with the help of cutter. The colour and moisture content of fresh ginger was noted. The initial moisture content of ginger was 89% wb and having l, a and b value were 58.6, 6.4 and 22.7 respectively.

3.1.2. Pretreatment

The samples were pretreated as per procedure reported by Schweiggert *et al* (2008). Ginger was blanched by tying the sample in muslin cloth and dipped for 5 min in hot water and subsequently dipped in cold water for 1 min to minimize losses of valuable compounds. The water was drained out.

3.1.3. Drying Procedure

The dryer was started half hour before actual drying experiment to achieve steady state conditions. The ginger

was put into the drying boxes according to the desired loading density to get the required bed depth. The temperature and relative humidity of the ambient, incoming and exhaust air were determined with the help of thermo-hygrometer placed on the surface of the sample. All these parameters were recorded at regular intervals. The sample was dried to a final moisture content of $\approx 35\%$ wb in multilayer drying and there after the sample was shifted to the microwave oven till the final moisture content $\approx 6\%$ db. The samples were allowed to come to room temperature, packed and stored. Three replications were taken for each experiment to get an average values.

3.2. Quality Parameters

The dried product was analyzed for its quality by estimating the rehydration ratio, coefficient of rehydration and shrinkage ratio, colour, oil content and overall acceptability.

3.2.1. Rehydration Ratio:

Rehydration ratio was evaluated by soaking known weight (5-10 g) of each sample in sufficient volume of water in a glass beaker (approximately 30 times the weight of sample) at 95°C for 20 minutes. After soaking, the excess water was removed with the help of filter paper and samples were weighed. In order to minimize the leaching losses, water bath was used for maintaining the defined temperature (Rangana 1986). Rehydration ratio (RR) was computed as follows:

Rehydration ratio,

$$RR = \frac{W_r}{W_d} \quad (3.1)$$

Where,

W_r = Drained weight of rehydrated sample, g.

W_d = Weight of dried sample used for rehydration, g.

3.2.2. Shrinkage Ratio:

The shrinkage ratio of dried sample was measured by toluene displacement method. Shrinkage ratio was calculated as the percentage change from the initial apparent volume (Rangana 1986).

$$\text{Shrinkage ratio} = \frac{V_r}{V_0} \quad (3.2)$$

Where,

V_r = Volume displaced by rehydrated sample, ml.

V_0 = Volume displaced by fresh sample, ml.

3.2.3. Colour:

The colour is described by tristimulus value of L, a, b with the positive value of a, b indicating red and yellow colour and negative values indicating green and blue colour respectively. For determination of colour the calorimeter was put on the sample and the values of L, a, b were measured. The colour change was determined using the formula:

Colour change

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad (3.3)$$

Where ΔL , Δa and Δb are deviations from L, a and b values of fresh sample.

3.2.4. Volatile Oil:

The estimation of volatile oil content in ginger is carried out in Clevenger apparatus by ASTA method (AOAC 2010) consisting of a round bottom flask, a volatile oil

determination tube and a condenser. First of all, 1000 ml of water and a few pieces of glass beads were added into a round-bottomed flask. Then, connect the round-bottomed flask to volatile oil determination tube. After that, 50g product was added in round bottom flask. Then, 2ml of xylene was added in the graduated tube by using a pipette and connected the reflux condenser to volatile oil determination tube. Then the flask was heated until boiling, continued the heating to allow the distillation proceed at a rate that would keep the middle part of the condenser cold. Heating was stopped after one and a half hour and trap was cooled to 20°C by immersing trap in suitable bath. The volume of xylene in the graduated tube of volatile oil determination tube was recorded. Then, subtracted the volume of xylene previously observed from the volume of oily layer, the difference in values gives the volume of volatile oil. The percentage of volatile oil is calculated as follows:

$$\text{Volatile oil (\%)} = \frac{\text{Volume of volatile oil} - \text{Vol of xylene in the blank}}{\text{Weight of the sample taken}} * 100$$

3.3. Optimization of Dehydration Process

In order to optimize multilayer cum microwave drying process for each exposure time, pause time and power level of treated material, only those responses were selected for optimization, which were found to be significant. The three dimensional plots and contour plots (graphical method) were drawn according to the fitted model and fixed variable.

3.4. Storage of Dried Ginger Flakes

Dried garlic flakes were packed in high density polyethylene (HDPE), low density polyethylene (LDPE) and laminate packages and samples were stored at ambient condition for six months.

3.4.1. Statistical Analysis for Quality of Stored Ginger Flakes

The data obtained for stored samples, packed in various packaging materials were analyzed for effect of type of packaging material and storage period on the quality of dried ginger flakes (developed under optimized conditions). The quality parameters studied were rehydration ratio (RR), Shrinkage ratio (SR), Colour change (CC), Oil content (OC) and overall acceptability (OA). The statistical analysis of data was done by using uni-variate analyses of variance (UNI-ANOVA) in general linear model using Statistical Package for Social Science (SPSS, 16.0). Means were computed and tested at 5 % level of significance.

III. RESULTS AND DISCUSSION

Study on convective-cum-microwave drying of ginger was carried out to evaluate the effect of exposure time, pause time and microwave power level on quality parameters of the dried product before and after storage. Multilayer drying of dried ginger was carried out at an air temperature of 60°C at air velocity of 3.5 m/s and loading density of 44.66 kg/m^2 upto a moisture content of $\approx 35\%$ wb (the point where drying rate became slow) followed by microwave drying to a moisture content of $\approx 6\%$ db (bone dry conditions) to overcome the slow removal of moisture

at the end (Andres *et al* 2004). The microwave drying of ginger was carried out at 3 levels of exposure time ranging between 5-25 s and 3 levels of pause time ranging between 10-100 s and microwave drying was carried out at 3 power levels ranging between 270-1350 W. The dried samples were optimized using surface response methodology. In addition, the impact of various parameters on quality of ginger was also investigated. The optimized dried ginger sample was then stored in different packaging material i.e. LDPE, HDPE and laminate packages for six months under ambient conditions.

4.1. Quality Parameters

The response and contour plots were generated for different interaction of three independent variables, keeping the value of other variables constant. Such a three dimensional surfaces could give accurate geometrical representation and provide useful information about the behaviour of the system within the experimental design. The complete experimental results for convective-cum-microwave drying of ginger have been presented in Table 4.1.

Table 4.1. Experimental data of drying of ginger for response surface analysis by convective-cum-microwave drying

Exposure	Pause	Power (W)	RR	SR	Color	Oil content	OA
5	10	810	4.22	1.59	11.54	1.32	8.5
5	100	810	4.09	1.64	11.41	1.36	8.5
5	55	1350	4.51	1.25	15.82	0.84	7.1
5	55	270	3.1	1.71	8.71	1.48	8.7
15	55	810	4.4	1.47	13.11	1.12	8.0
15	55	810	4.49	1.41	14.63	1.06	8.1
15	55	810	4.38	1.48	13.92	1.16	8.2
15	55	810	4.47	1.43	13.19	1.04	7.9
15	55	810	4.41	1.45	13.53	1.10	8.0
15	10	270	3.76	1.5	9.81	1.26	8.1
15	100	1350	4.71	1.2	16.52	0.80	7.0
15	100	270	3.3	1.55	10.11	1.28	8.2
15	10	1350	4.81	1.16	17.03	0.78	6.9
25	55	1350	4.94	1.14	17.66	0.76	6.8
25	10	810	4.79	1.3	14.05	0.92	7.4
25	100	810	4.59	1.39	13.87	0.92	7.6
25	55	270	3.93	1.38	10.91	0.96	7.5

4.1.1 Rehydration ratio

The Rehydration ratio (RR) of dried ginger varied in the range of 4.94-3.10 with an average value of 4.02. The maximum rehydration ratio of 4.94 was found in sample with 25s ET, 55s PT and 1350 W PL; while minimum rehydration ratio of 3.10 was found for 5s ET, 55s PT, and 270W PL.

From power level-pause time contour map (Fig 4.1), it was observed that at a constant pause time (10s) RR increased with increasing power level. At a constant power level, pause time has no effect on RR. From exposure time – microwave power level contour map (Fig 4.2) it was observed that RR increased with increase in both power level and exposure time.

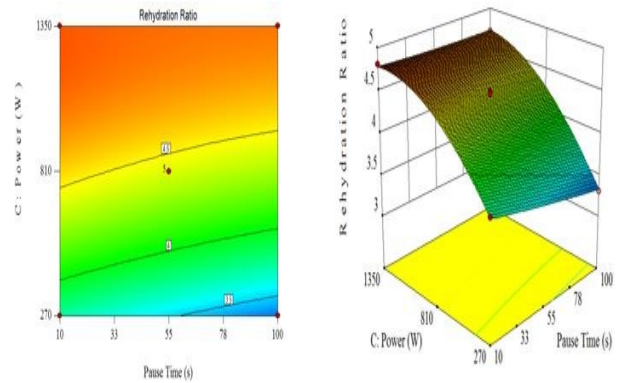


Fig 4.1. Contour and response surface plots showing effect of pause time and microwave power level on RR.

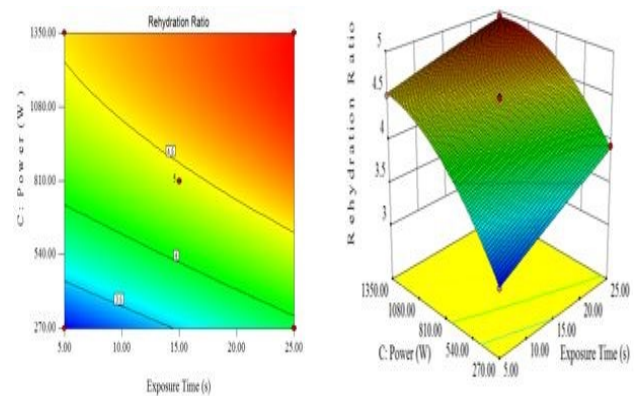


Fig 4.2. Contour and response surface plots showing effect of exposure time and microwave power level on RR.

4.1.2. Shrinkage Ratio

The shrinkage ratio (SR) of ginger varied in the range of 1.14-1.71 with an average value of 1.425. The maximum shrinkage ratio of 1.17 was found at 5s ET, 55s PT and 270W PL; while minimum shrinkage ratio of 1.14 was found at 25s ET, 55s PT and 1350W PL.

From power level–pause time contour map (Fig 4.3), it was observed that SR decreased with increasing power level. At a constant pause time (10s) SR decreased from 1.45 at 270W PL to 1.10 at 1350W PL. At a constant power level, pause time has no effect on SR.

From exposure time-microwave power level contour map (Fig 4.4), it was observed that SR decreased with increase in both power level and exposure time.

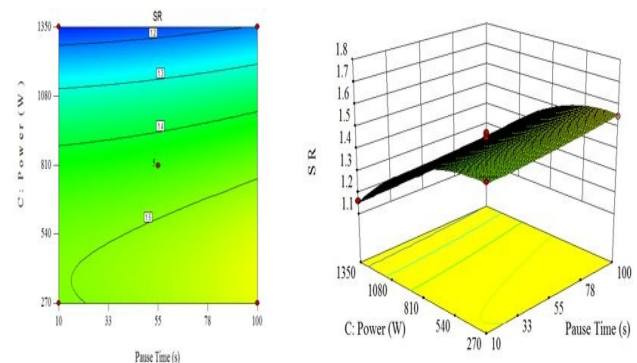


Fig 4.3. Contour and response surface plots showing effect of pause time and microwave power level on SR

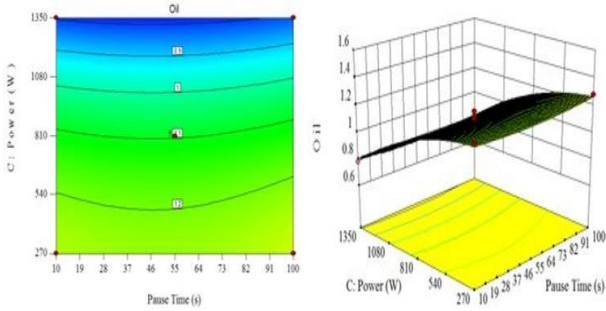


Fig. 4.4. Contour and response surface plots showing effect of exposure time and microwave power level on SR

4.1.3. Oil Content

The oil content of ginger varied in the range of 0.76-1.48% with an average value of 1.12 %. The maximum oil content of 1.48 % was found at 5s ET, 55s PT and 270W PL; while minimum oil content of 0.76 was found at 25s ET, 55s PT and 1350W PL.

From power level-pause time contour map (Fig 4.5), it was observed that oil content decreased with increase in power level.

From exposure time-microwave power level contour map (Fig 4.6) it was observed that oil content decreased with increase in both exposure time and power level.

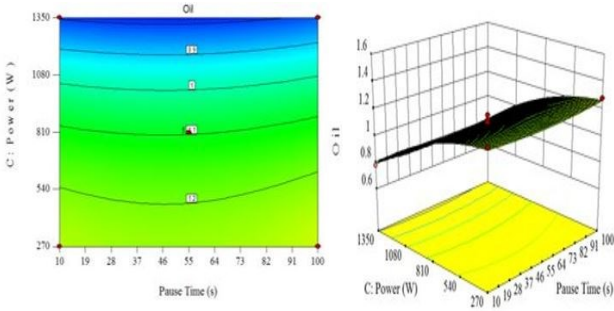


Fig. 4.5. Contour and response surface plots showing effect of pause time and microwave power level on oil content.

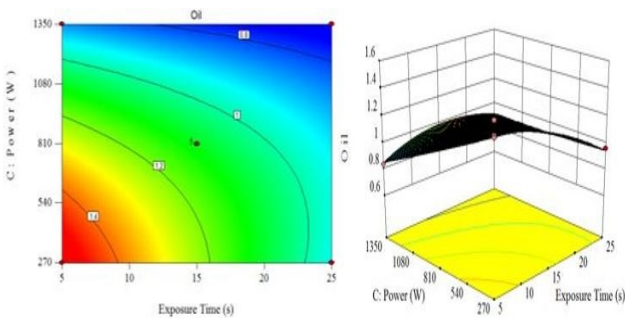


Fig. 4.6. Contour and response surface plots showing effect of exposure time and microwave power level on oil content.

4.1.4. Colour

The colour change of ginger varied in the range of 8.71-17.66 with an average value of 13.185. The maximum colour change of 17.66 was found at 25s ET, 55s PT and 1350W PL; while minimum colour change of 8.71 was found at 5s ET, 55s PT and 270W PL.

From pause time - power level contour map (Fig 4.7), it was observed that colour change increased with increase in power level. From exposure time – power level contour map (Fig. 4.8), it was observed that colour change increased both with exposure time and power level (Maskan 2001 b).

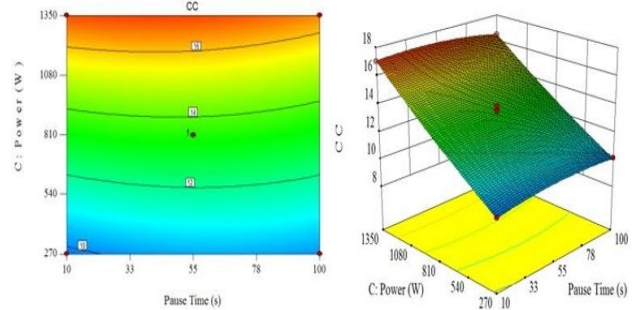


Fig. 4.7. Contour and response surface plots showing effect of pause time and microwave power level on color change.

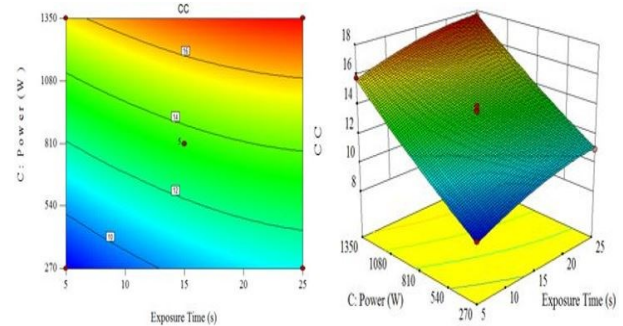


Fig. 4.8. Contour and response surface plots showing effect of exposure time and microwave power level on color change.

4.1.5. Overall Acceptability

The overall acceptability (OA) of ginger varied in the range of 8.70-6.80 with an average value of 7.75. The maximum overall acceptability of 8.70 was found at 5s ET, 55sPT and 270W PL; while minimum overall acceptability of 6.80 was found at 25s ET, 55s PT and 1350W PL.

From power level-pause time contour map (Fig 4.9), it was observed that OA decreased with increase in power level. From exposure time-microwave power level contour map (Fig 4.10) it was observed that OA decreased with increase in both power level and exposure time.

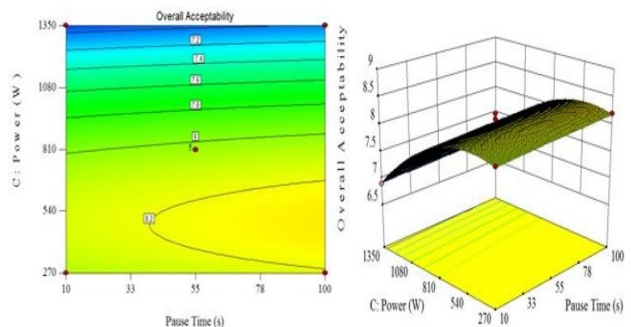


Fig. 4.9. Contour and response surface plots showing effect of pause time and microwave power level on overall acceptability

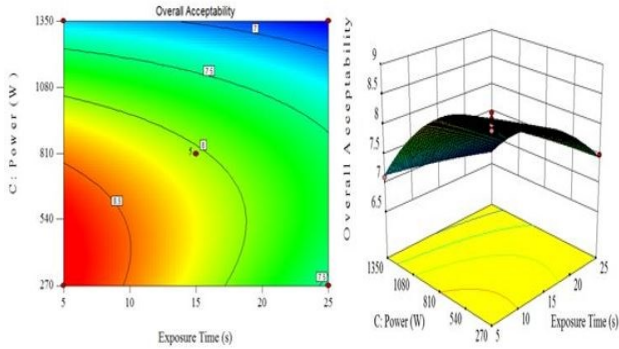


Fig. 4.10. Contour and response surface plots showing effect of exposure time and microwave power level on overall acceptability

4.2. Optimization of Convective-Cum-Microwave Drying of Ginger

The optimum values of process parameters and responses are presented in Table 4.2. The process conditions for microwave drying of ginger were optimized using numerical optimization technique. The main criteria for constraints optimization were maximum possible rehydration ratio, volatile oil, overall acceptability and minimum possible shrinkage ratio, color change (Themelin *et al* 1997; Ade-Omowaye *et al* 2002). The visual representation (appearance) of product dried at optimum condition of exposure time, pause time and microwave power level (8.6s, 55s and 810W) are presented in Fig 4.11.

Table 4.2. Optimum values of process parameters and responses

Process parameters	Goal	Lower limit	Upper limit	Importance	Optimization level
A: exposure time (s)	In range	5	25	3	8.6
B: pause time(s)	In range	10	100	3	55
C: Power level (W)	In range	270	1350	3	810
Responses					Predicted value
Rehydration ratio	Maximize	3.1	4.94	3	4.24
Shrinkage ratio	Minimize	1.14	1.71	3	1.54
Color change	Minimize	8.71	17.66	3	12.58
Volatile oil	maximize	0.38	0.74	3	1.21
Overall acceptability	Maximize	6.8	8.7	3	8.31

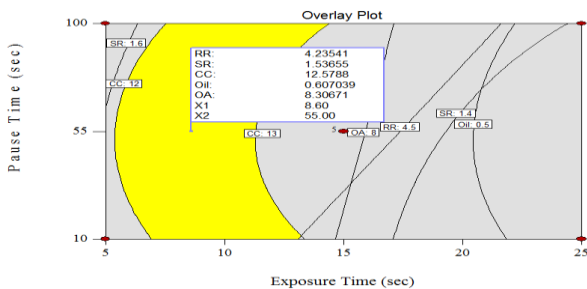


Fig. 4.11. Superimposed contour plot of different responses for optimization of convective cum microwave dehydration of ginger

4.3. Storage of Dried Ginger Flakes

4.3.1. Effect of Storage Period on Rehydration Ratio

The rehydration ratio of the stored product decreased with the increase in storage period (Fig 4.12). The maximum variation (3.82 to 4.45) in rehydration ratio with storage period was observed in LDPE packed sample and minimum in HDPE (4.45-4.00) and laminate (4.45-4.01). The univariate ANOVA also corroborated the results showing that the storage period and packaging material has significant effect on overall acceptability at 5% level of significance.

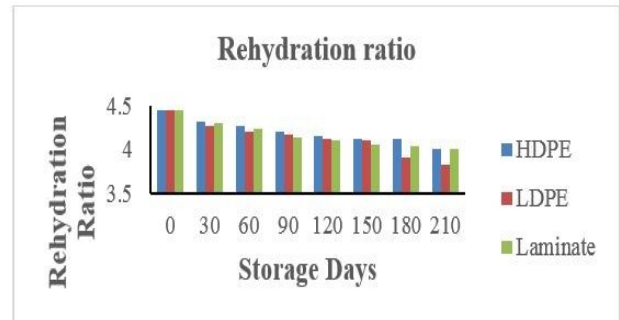


Fig. 4.12. Variation in rehydration ratio with storage period

4.3.2. Effect of Storage Period on Shrinkage Ratio

The shrinkage ratio of the stored product increased with the increase in storage period (Fig 4.13). The maximum variation (1.40 to 1.57) in shrinkage ratio with storage period was observed in LDPE packed sample and minimum in HDPE (1.40-1.49) and laminate (1.40-1.52). The univariate ANOVA also corroborated the results showing that the storage period and packaging material has significant effect on overall acceptability at 5% level of significance.

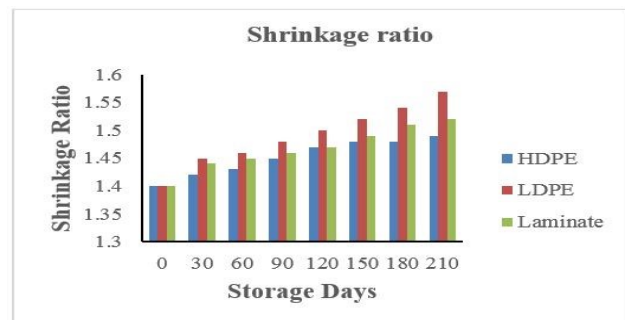


Fig. 4.13. Variation in shrinkage ratio with storage period

4.3.3. Effect of Storage Period on Colour Change

The colour change of the stored product increased with the increase in storage period (Fig 4.14). The maximum variation (13.20 to 14.53) in colour change with storage period was observed in LDPE packed sample and minimum in HDPE (13.20-14.42) and laminate (13.20-14.50). The univariate ANOVA also corroborated the results showing that the storage period and packaging material has significant effect on overall acceptability at 5% level of significance.

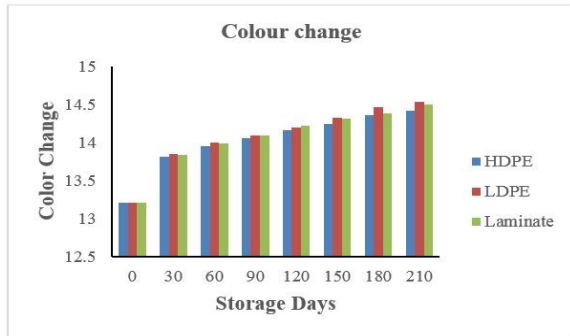


Fig. 4.14. Variation in colour with storage period

4.3.4. Effect of Storage Period on Oil Content

The oil content of the stored product decreased with the increase in storage period (Fig 4.15). The maximum variation (0.92 to 1.32%) in oil content with storage period was observed in LDPE packed sample and minimum in HDPE (1.10-1.32%) and laminate (1.08-1.32%). The univariate ANOVA also corroborated the results showing that the storage period and packaging material has significant effect on overall acceptability at 5% level of significance.

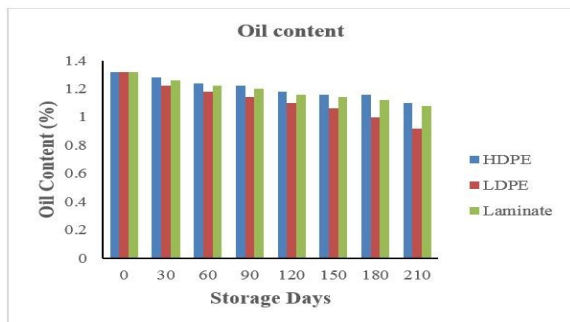


Fig. 4.15. Variation in oil content with storage period

4.3.5. Effect of Storage Period on Overall Acceptability

The overall acceptability of the stored product decreased with the increase in storage period (Fig 4.16). The maximum variation (7.30-8.30) in OA with storage period was observed in LDPE packed sample and the minimum variation in OA was observed in HDPE (7.50-8.30) and laminate (7.40-8.30). The univariate ANOVA also corroborated the results showing that the storage period and packaging material has significant effect on overall acceptability at 5% level of significance.

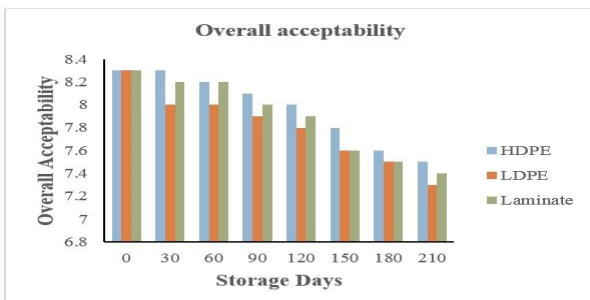


Fig. 4.16. Variation in overall acceptability with storage period

IV. CONCLUSION

The objective of the convective-cum-microwave drying was to reduce the drying time and to check the quality parameters of the dried ginger during storage. The above experiment showed that the quality of the dried ginger was almost same before and after the storage. It was observed that the maximum variation was seen in LDPE package, while the quality parameters were comparable for HDPE and laminate packages.

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