Effect of Blanching and Drying Temperatures on Various Physico-chemical Characteristics of Green Beans

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ABSTRACT

Fresh green bean samples (un-blanched and blanched) were dried at 50, 60 and 70 °C, followed by studying the effect of blanching treatment and drying temperature in various characteristics and storage study in HDPE and LDPE packaging material. The blanched dried green bean samples showed lower ash content but higher rehydration ratio, chlorophyll content and carbohydrate content than un-blanch dried green bean samples. No significant change in moisture, protein, fat and fibre content was observed after blanching. The green beans were dried up to the moisture content of 14±0.5 from an initial moisture content of > 90 %. The increase in the drying temperature reduced the drying time. Blanching treatment enhanced the drying rate, the kinetics parameter showed that the value of ‘k’ ranged from 0.008-0.013 and 0.009-0.015/min in un-blanch and blanch samples respectively. The drying temperature caused decrease in color parameters, chlorophyll content, however RR was observed to increase with the drying temperature. The moisture, chlorophyll content, color values (L* a* b*) and rehydration ratio was observed to decrease with the storage. The better desirable quality attributes of green beans were retained in HDPE as compared to LDPE. In conclusion it was suggested that drying temperature effects the quality attributes of the green beans and also the packaging material also influence the storage stability of the dried green beans.

Keywords: Blanching, Chlorophyll, Color, Drying, Green beans, Rehydration.

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INTRODUCTION

Green bean (Phaseolus vulgaris), is an annual herbaceous plant belonging to Fabaceae family that originated in Central and South America. Green beans are produced worldwide; in 2016 the total production of green beans was around 26.8 million tonnes. China is the largest producer followed by Indonesia, India, Turkey, Thailand, and Egypt, Indian alone produced around 620,000 tons green beans (FAOSTAT, 2018). When common bean is used for its unripe fruit, it is called as green bean or snap bean (Sotelo et al. 2003). The green beans are good source of vitamins, proteins and a significant source of minerals for low-income population (Laparra et al. 2009). Vitamin A and C present in green beans are excellent antioxidants that reduces the amount of free radicals in the body and prevent the building up of plaque in arteries and veins Soares, et al. 2015.

Green beans are highly perishable due to high moisture content (more than 90 %), thus they are vulnerable to microbial spoilage. Additionally the growth of beans is rapid at the time of harvest and exhibit comparatively higher respiration rate, even when held at low temperatures (Watada & Morris, 1967, Maldonado et al. 1996). Green beans are occasionally cold stored for processing or favourable markets and can be stored up to 8-12 days under refrigerated conditions. Longer storage or higher temperatures hasten yellowing, seed development, and toughening of the pods as they contain high moisture content (WFLO-Worlds Food Logistis Organisation., 2008). However to extend their shelf life to many moths the drying process is most common method of green beans preservation.

Drying is a heat and mass transfer operation during which moisture is removed for the food material. The prime objective of drying is preservation by reducing the water activity hence enhancing the shelf life by reducing the possibility of microbial growth thus spoilage of food stuffs. Another objective is to reduce the bulk so that the product would be convenient and economical to handle, transport and store (Domyaz 2005 and 2011). Dried vegetables have great potential to use throughout the year for preparation of several types of mix vegetables and other recipes such as ingredient of ready to cook instant noodles, soup mixes etc. Traditional and conventional sun drying has many disadvantages which can be minimized by the mechanical hot air drying (Doymaz& Pala, 2002). Hot air drying has gained importance because it has many advantages over sun drying, such as shorter drying times, lower labour costs, less microbial contamination, weather independent, controllable drying parameters which give more uniform and hygienic product with less quality degradation, (Barbosa-Canovas & Vega Mercado, 1996).
Drying characteristics of green beans have been studied by many authors. There have been many studies on the drying behaviour of green beans such as Yaldiz and Ertekin, 2010 (green beans and okra); Senadeera et al., 2003 (green beans); Doymaz et al., 2005 (green beans); Doymaz, 2011 (green beans and okra); Doymaz et al., 2015a (green beans); Doymaz et al., 2015b (green beans). However, any study regarding the effect of blanching on the drying and quality characteristics of green beans and their storage behaviour has not been found reported in literature to the best knowledge of the authors of the present study. Therefore, the present investigation was undertaken to study the effect of blanching treatment on drying characteristics and various parameters of dried green beans and their storage study.

**Materials and Methods**

Fresh green beans were procured from local market of Awantipora, Kashmir India and kept in refrigerator (Model: GL-B285BGPN) at 5±2°C prior to use not more than 10 hours. Before drying process, green beans were washed, both ends were rejected and endless green beans were cut manually into pieces of length of 1.5 ± 0.1 cm. The green beans were further subdivided into 2 equal portions, one portion of green beans was pre-treated prior to drying by using the method of blanching given in Agarwal et al. 2015 and other portion was dried without any treatment (un-blanched).

**Standardization of blanching treatment**

A known quantity (100 g) of green beans was taken in a muslin cloth and dipped in boiling water containing 0.5% sodium meta-bi-sulphite, 0.1% magnesium oxide,0.1% sodium bicarbonate (1:5, W/W) for 1, 2, 3, 4 and 5 minutes for blanching treatment. Blanching time was standardized by checking the peroxidase activity with the help of peroxidase test solution (1% guaiacol and 2% hydrogen peroxide, 1:1).

**Peroxidase activity test**

The enzyme activity test was carried out by following the method described by Nleya et al. 2014. Ten randomly selected green bean pieces were cut into halves longitudinally and the 20 halves were arranged with cotyledon surface exposed and sprayed with peroxidase test solution. When the brown color developed in more than one out of 20 halves within 10 seconds of time after spraying the test solution, the treatment was considered as inadequate, the test was carried out in triplicates.

**Drying of the green beans**

The drying process was carried out in laboratory scale hot air dryer (Vindhawashani Engineering, New Delhi India). Both un-blanched and blanched samples were distributed uniformly in a single layer on the stainless steel tray, and dried at 50, 60 and 70 °C air temperatures. The change in weight during drying of each samples was measured at an interval of 30 min. The samples were dried up to the final moisture level of 14±0.5%.

To find out the rate constant ‘k’ (min⁻¹) the change in moisture content with drying time was fitted to an exponential model, Eq. 1.

\[
MC = MC_0 e^{-k_t}
\]

Eq. (1)

Where MC₀ and MC is the moisture content (d.b.)

**Packaging and storage**

Dried green bean samples were packed in different packaging materials: LDPE (Low Density Polyethylene) and HDPE (High Density Polyethylene) pouches. Packed samples were stored at ambient temperature up to 2 months for storage. The physicochemical analysis of the stored products was carried out at an interval of 30 days during storage.

**Proximate analysis**

The fresh as well as dried green bean samples were analysed for moisture, ash, crude protein, crude fibre, crude fat and carbohydrate content, all the parameters were determined by standard methods of AOAC 1990. The moisture content was estimated by oven drying method at 100-105°C to constant weight. Ash content was determined by incineration in muffle furnace (NSW-101/ Narang Scientific Works PVT. LTD. New Delhi, India) maintained at 550-600°C for 5-6 h, protein by micro-Kjeldahl method, fat by Soxhlet extraction method and crude fibre was estimated by using dilute acid (H₂SO₄) and alkali (NaOH) hydrolysis. The total carbohydrate content was calculated by difference method using Eq. 2.

\[
\text{Carbohydrate} = 100 - (\text{moisture} + \text{ash} + \text{fat} + \text{protein} + \text{crude fibre})
\]

Eq. (2)

**Color analysis**

The color of fresh as well as dried green bean samples was determined by using Colorimeter (Hunter Lab Color flex EZ Model No. 45/0). This instrument was calibrated by using supplied black and white tile provided with the instrument. The color parameters L* (lightness), a* (green to redness) and b* (blue to yellowness) were determined for every sample. Three readings were performed for each sample, and the corresponding mean and standard deviation were calculated.

**Chlorophyll analysis**

Chlorophyll content was determined by spectrophotometer method as recommended by Sadasivam and Manickam (1992). One gram of sample was crushed with 20 mL of 80% acetone repeatedly in mortar and pestle. The extract was removed and the residue was crushed repeatedly until the residue was colorless. The extracts were filtered into 100 mL volumetric flask and made volume up to 100 mL with 80% acetone. The absorbance of the final volume was measured using UV-Vis spectrophotometer at the wavelength of 645, 663nm against blank solvent (80 % acetone), and the chlorophyll content was calculated by Eq. 3.

\[
\text{Total chlorophyll (mg/g)} = 20.2 (A_{663}) + 8.02 (A_{645}) \times \frac{V}{1000} \times W
\]

Eq. (3)
Where, $V$ = Final volume of chlorophyll extract in 80 % acetone and $W$ = Fresh weight of the tissue extracted.

**Rehydration ratio**
Rehydration is a process of refreshing the dried material in water. The rehydration ratio was calculated by the method as recommended by Doymaz et al. (2015a). About 3 grams ($W$) of dried sample were placed in glass beakers containing water (at room temperature 25±2 °C) at a ratio of 1:100 (w/w) for 5 hours. The samples were stained and the excess water from the sample surface was removed by using tissue paper followed by the weighing ($W_f$). The rehydration ratio (RR) was calculated using Eq. 4.

$$RR_{(g\text{ water/dry matter})} = \frac{W_f - W}{W_f} \quad \text{Eq. (4)}$$

Where, $W$ = Weight of dried material and $W_f$ = Weight of rehydrated material.

**Statistical analysis**
The experiments were run in triplicates and the mean values with standard deviations were reported. SPSS software (SPSS 16, Inc, Chicago, IL, USA) was used for Two-way Analysis of Variance (ANOVA) and Tukey’s range Post-hoc test was used to identify the significant difference at 95% confidence level ($\alpha = 0.05$). The present study only discusses the main effects as the interactions were found not significant.

**RESULT AND DISCUSSION**
The fresh green beans were analyzed for moisture, ash, fat, protein, fibre, carbohydrate, color and chlorophyll. The results are presented in Table 1 and are almost similar to those reported by Doymaz et al., 2015a; Doymaz et al., 2015b; Belitz et al., 2009.

**Peroxidase activity**
Peroxidase is used as an indicator enzyme to evaluate adequacy of blanching because of its highest thermal resistance among all the enzymes (Gunes & Bayindirh., 1993). Peroxidase activity was measured by color development within 10 seconds after spraying the test solution of guaiacol and $H_2O_2$ (Nleya et al., 2014). From the results, it was observed that green bean samples in blanching solution for 3 or more than 3 min showed no peroxidase activity or negative peroxidase test. No brown color development was witnessed as the test solution was sprayed in samples blanched for more than 3 min. Therefore the 3 min of blanching time was selected as standard blanching time for green beans and was used for further experiment in the present study. Further the un-blanched and blanched (3 min) green bean samples were dried at three different temperatures viz 50, 60 and 70 °C up to the moisture content of 14±0.5 %.

**Drying of blanched and un-blanched green beans**
The initial average moisture content of green beans was observed to be more than 90 %. The samples were dried at three different temperatures (50, 60 and 70 °C) until the final moisture content reached to 14 ±0.5 %. The drying curve at 50, 60 and 70 °C are presented in Figure 1. It is apparent that the moisture content decreased with drying time and decreased faster at higher drying temperature in all the samples. Blanched samples showed shorter drying time than un-blanched samples, thus the drying time required to reach final moisture content of samples was 480, 360 and 300 min in case of un-blanched samples and 420, 300 and 240 min in case of blanched samples at drying temperature of 50, 60 and 70 °C, respectively. This phenomenon can be explained by the fact that in addition to the enzyme inactivation blanching resulted in tissue softening, subsequently resulting in faster moisture removal by enhancing moisture transfer from inside the samples to the surface (Kshetrimayum et al., 2015). The most effectual force governing the moisture movement in the agricultural products is diffusion and rate of diffusion can be enhanced with rise in temperature of heat input (Pardeshi et al., 2009). Thus, at higher drying temperature the higher heat absorption resulted in higher product temperature and relatively faster rate and consequently shorter drying time (Doymaz et al., 2015b). Similar observations were also reported by Shete et al. (2015) in green peas; Tunde-

**Table 1:** Physicochemical composition of fresh green beans

| Component              | Amount         |
|------------------------|----------------|
| Moisture (g/100g)      | 90.39±0.40     |
| Ash (g/100g)           | 0.50±0.00      |
| Protein (g/100g)       | 1.82±0.60      |
| Fat (g/100g)           | 0.23±0.05      |
| Crude fibre (g/100g)   | 3.37±0.20      |
| Carbohydrate (g/100g)  | 3.69±0.10      |
| Chlorophyll content (mg/100g) | 14.92±0.12 |
| Color value            |                |
| L*                     | 50.9 ± 0.75    |
| a*                     | -11.01 ± 0.35  |
| b*                     | 20.62 ± 0.51   |

Figure 1: Drying curve of blanched (B) and un-blanched (UB) green beans dried at different temperatures (legends show actual data and dotted line (- - - -) shows model line.
The effect of blanching and drying temperatures was analyzed on various physicochemical characteristics of green beans. Akintunde (2014) in bell pepper; Rajeshwari et al. (2013) in amaranth leaves; Doymaz et al. (2015a) in green beans.

The kinetic parameters are presented in Table 2, the determination coefficient or $R^2$ value of all the drying curves ranged from 0.993-0.999. Thus, the change in moisture content with drying time was well described by exponential reduction as depicted in Figure 1. The rate constant ‘k’ increased with increasing the drying temperature; however, the effect of blanching on drying rate was fairly witnessed by the value of the ‘k’. The value of ‘k’ ranged from 0.008-0.013 and 0.009-0.015/min in un-blanched and blanched samples respectively, indicating the higher rate of drying in blanched samples than that of un-blanched. The un-blanched and blanched green bean samples dried at different temperatures up to the moisture content of 14 °0.5 % are presented as Figure 2 and 3 respectively.

**Effect of blanching and drying temperatures on physicochemical parameters**

**Proximate composition**

Moisture, crude fat, and crude protein was not significantly affected by blanching and drying temperatures as shown in Table 3 and was found to be in the range of (13.88–14.09), (1.98–2.07) and (18.12–18.29), respectively. Gouveia et al. (2014); Doymaz et al., 2015a; Doymaz et al., 2015b also reported similar results in dried green beans. The ash content of both un-blanched and blanched dried green beans decreased significantly ($p\leq0.05$) from 4.87-4.33% and 4.41-3.96%, respectively with the increase in drying temperature. This lower ash content at high temperature may be due to high drying temperature resulting in the degradation of micronutrients. Similar trend was also reported by Reis et al.

**Table 2:** Exponential Model parameters of drying of blanched and unblanched green beans

| Treatment  | Drying Temperature | $MC_0$ (g/g dry weight) | -k $(min^{-1})$ | $R^2$ |
|-----------|--------------------|-------------------------|-----------------|-------|
| Un-blanched | 50                 | 9.296                   | 0.008           | 0.995 |
|           | 60                 | 8.761                   | 0.010           | 0.997 |
|           | 70                 | 9.461                   | 0.013           | 0.999 |
| Blanched  | 50                 | 8.903                   | 0.009           | 0.996 |
|           | 60                 | 8.604                   | 0.012           | 0.993 |
|           | 70                 | 9.738                   | 0.015           | 0.999 |
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| Parameter             | Un-blanched and dried | Blanched and dried |
|-----------------------|-----------------------|--------------------|
| Drying Temperature (˚C) | 50 | 60 | 70 | 50 | 60 | 70 |
| Moisture %            | 14.09±0.00<sup>a</sup> | 14.00±0.11<sup>a</sup> | 13.90±0.15<sup>a</sup> | 14.00±0.11<sup>a</sup> | 13.96±0.08<sup>a</sup> | 13.88±0.05<sup>a</sup> |
| Fat %                 | 2.07±0.06<sup>a</sup> | 2.01±0.05<sup>a</sup> | 1.99±0.02<sup>a</sup> | 2.06±0.04<sup>a</sup> | 1.98±0.03<sup>a</sup> | 1.98±0.03<sup>a</sup> |
| Ash %                 | 4.87±0.13<sup>a</sup> | 4.58±0.11<sup>b</sup> | 4.33±0.06<sup>c</sup> | 4.41±0.02<sup>c</sup> | 4.13±0.04<sup>d</sup> | 3.96±0.06<sup>e</sup> |
| Protein %             | 18.29±0.05<sup>a</sup> | 18.25±0.06<sup>a</sup> | 18.23±0.05<sup>a</sup> | 18.18±0.08<sup>a</sup> | 18.15±0.08<sup>a</sup> | 18.12±0.09<sup>a</sup> |
| Fibre %               | 15.06±0.11<sup>a</sup> | 14.90±0.08<sup>b</sup> | 14.69±0.09<sup>c</sup> | 14.97±0.10<sup>c</sup> | 14.77±0.01<sup>b</sup> | 14.59±0.11<sup>c</sup> |
| Carbohydrate %        | 45.62±0.10<sup>d</sup> | 46.26±0.15<sup>de</sup> | 46.86±0.1<sup>ic</sup> | 46.38±0.12<sup>d</sup> | 47.01±0.12<sup>b</sup> | 47.47±0.11<sup>ic</sup> |
| RR (g water/g dry matter) | 2.26±0.17<sup>f</sup> | 2.73±0.11<sup>e</sup> | 2.95±0.14<sup>d</sup> | 3.41±0.18<sup>a</sup> | 3.75±0.13<sup>b</sup> | 4.14±0.12<sup>a</sup> |
| Chlorophyll (mg/100g) | 82.51±0.09<sup>b</sup> | 73.22±0.14<sup>c</sup> | 64.29±0.17<sup>de</sup> | 88.54±0.19<sup>c</sup> | 79.93±0.17<sup>c</sup> | 73.78±0.15<sup>d</sup> |

**L***<sup>a</sup> 41.76±0.98<sup>a</sup> 40.08±0.22<sup>b</sup> 39.60±0.53<sup>c</sup> 24.90±0.26<sup>d</sup> 21.94±0.52<sup>e</sup> 21.02±0.18<sup>f</sup>

**a***<sup>a</sup> -4.78±0.43<sup>b</sup> -4.10±0.13<sup>a</sup> -3.98±0.16<sup>b</sup> -4.57±0.96<sup>c</sup> -3.69±0.42<sup>ab</sup> -3.13±0.79<sup>f</sup>

**b***<sup>a</sup> 17.45±0.25<sup>a</sup> 15.92±0.14<sup>b</sup> 15.90±0.10<sup>c</sup> 12.57±0.88<sup>d</sup> 11.43±0.63<sup>ab</sup> 9.39±0.72<sup>e</sup>

<sup>***Values with different letters in same row showed statistically significant differences at a 5% level, according to Duncan’s multiple range test.</sup>

2013 who have studied the effect of drying temperatures on the nutritional and antioxidant qualities of cumari peppers (capsicum Chinese). Blanched dried samples also showed significantly (p≤0.05) lower ash content compared to un-blanched dried samples, such an effect might be due to transfer of minerals from samples to boiling water (Nnamani et al. 2009). Similar results were reported by Gouveia et al. (2014) for common beans (phaseolus vulgaris L.) and Tandon, (2006) for dehydrated green pea varieties.

The crude fiber content of dried green beans decreased significantly (p≤0.05) with the increase in drying temperature (Table 3). No significant change was found between blanched and un-blanched dried samples. Reis et al. (2013) also showed decrease in crude fibre with increase in drying temperature. Bello et al. (2008) reported that crude fiber consists of cellulose, hemicellulose and lignin components whose compositions are affected during hydration of food and hemicellulose, pectin and hydrocolloids are easily solubilized by high heat and this may be the reason for above reduction in crude fibre content (Udousoro and Etuk., 2012).

Carbohydrate content of all dried green beans presented in Table 3 was found in the range 46.38 - 46.86 % after drying. Blanched dried samples showed significantly (p≤0.05) more carbohydrate content than un-blanched dried samples which might be attributed to the breakdown of ketogenic amino acids to glucose during blanching thereby increasing the carbohydrate content of dried green bean samples (Fadupin et al. 2014). Similar trend was also reported by Traore et al. (2017) in dehydrated amaranth leaves. Also there was a significant (p ≤ 0.05) increase in carbohydrate content with increase in drying temperature. Carbohydrate content depends on the other parameters of dried green beans as it is calculated from moisture, ash content, protein content, fat content and crude fiber. Akalaki et al. (2015) also reported similar behaviour in dehydrated moringa oleifera leaves.

**Chlorophyll content**

Chlorophylls are the pigments that confer green color to foods of plant origin. These pigments are particularly unstable under most conditions relevant for food processing and preservation (Belitz et al., 2009; Koca et al., 2006). The loss of green color and the color change to yellow or brown hues is due to chlorophyll degradation (Hortensteiner & Krautler, 2011). The chlorophyll content of dried green beans dried at different temperatures are presented in Table 3 and was found in the range of 64.29 - 82.51 mg/100g (un-blanched dried) and 73.78 - 88.54 mg/100g (blanched dried) after...
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drying at a temperature range of 50-70°C respectively. Blanched dried samples showed significantly (P≤0.05) higher chlorophyll content in comparison to un-blanched dried samples. Results found here are in contradiction with Priyanka et al. (2017) in green beans, Pavani and Aduri, (2018) in green leafy vegetables, might be due to the effect of sodium bicarbonate used in blanching solution. Sodium bicarbonate has a positive effect on stability of chlorophyll as it reacts with chlorophyll, displacing the phytol group forming a bright green chlorophyllide (Srilakshmi, 2003). In addition, sodium bicarbonate increases the medium pH which, by itself, improves chlorophyll stability as it leads to equilibrium between positive and negative charges, decreases chlorophyll degradation (Von Elbe, 2000). The most important positive impact of blanching with sodium bicarbonate is the removal of phytol chain, otherwise it would react with singlet oxygen, or hydroxyl and peroxy radicals generated during chlorophyll degradation (Rontani et al., 1995). Singlet oxygen radical attacks the double bonds of the chlorophylls directly, producing hydroperoxides that are further cleaved to produce radicals (Chen and Huang, 1998). Additionally the chlorophyll content decreased with the increase of the drying temperature, that might be attributed to the conversion of chlorophylls to pheophytins at higher temperatures (Steel and Tong, 1996; Yin et al., 2007; Koca et al., 2006).

Color values
Color is a major food quality attribute. Color change is a quality criterion for assessing the quality of dried products. The results of color parameters are presented in Table 3. The L* and -a* value, which show the whiteness and greenness of the product, ranged between 21.02 & 41.76 and -3.13 & -4.78 respectively after drying. Blanched dried green beans were found to have lower L*, -a* and b* values than un-blanched samples. This means that blanched samples were darker green in color (lower -a* value and lower b* value) than un-blanched samples that were lighter green in color (higher L* values; higher -a* values) after drying as shown in Figure 2 and 3. Such an effect might be due to destruction of browning enzymes during blanching which would otherwise cause browning. The results are in agreement with findings of Pathare et al., 2013. As the drying temperature was increased the hunter values showed decreasing trend because of Maillard reaction caused by higher temperature. In addition, higher temperature changing color from green or bright

Figure 4: Rehydrated un-blanched sample and dried at (a) 50, (b) 60 and (c) 70 °C

Figure 5: Rehydrated blanched sample and dried at (a) 50, (b) 60 and (c) 70 °C
green to olive brown as a consequence of conversion of chlorophyll to pheophytin (Steel and Tong, 1996) and higher accumulation of pheophytins decreasing-a* coordinate (Weemas et al., 1999). Doymaz et al. (2015)a also found same trend while working on characteristics of thin-layer infrared drying of green beans.

Storage study of the dried green beans

Changes in proximate composition during storage
As the days of storage progressed, the moisture content of all dried green bean samples packed in different packaging materials increased significantly (p≤0.05) shown in Table 4. This increase in moisture content might be due to the hygroscopic nature of dried vegetables that absorb the atmospheric moisture during storage. Singh et al. (2003); Kalaskar et al. (2012); Seevaratnam et al. (2012) also reported the similar behavior during storage of green leafy vegetables. With regard to packaging materials, a significant change was found between HDPE and LDPE, the rate of increase in moisture was low in samples packed in HDPE compared to LDPE during storage. This effect might be attributed to less permeability of HDPE film to water vapor compared to LDPE (Singh and Sagar, 2010).

Changes in ash, protein, fat and fiber content during storage are presented in Table 4. With the increase in storage progression, the ash content, protein content, fat content and fiber content of all dried green bean samples showed a non-significant change between storage periods and packaging materials. The ash and fiber could not be decreased during storage as it is the inorganic residue remained after the water and organic matter. Singh et al. (2003) also reported non-significant change in ash content and protein during storage in dehydrated carrot and leafy vegetables.

Changes in carbohydrate content of dried green beans during storage are shown in Table 4. As the days of storage progressed, the carbohydrate content of all dried green bean samples showed significantly (p≤0.05) decreasing trend. Regarding the mode of packaging, samples packed in HDPE and LDPE show a significant change in carbohydrate content during storage. This decrease in carbohydrate content might be due to increase in moisture of dried green beans with storage which resulted in decrease in carbohydrate content as it was calculated from difference method (Mills & Woods, 1994).

Changes in rehydration ratio during storage
The changes in rehydration ratio of dried green beans during storage are shown in Table 5. With regard to storage, the rehydration ratio showed significantly (p≤0.05) decreasing trend with increase in storage period. This decreased pattern in rehydration ratio during storage may be attributed to moisture stress, structural and chemical changes during storage, Gupta et al. (2012). Similar trend was also reported by Kalaskar et al. (2012), Singh and Sagar, (2010). HDPE film showed higher values of RR than LDPE which might be due to less absorption of moisture in HDPE during storage. Similar behaviour was reported by Pavani and Aduri, (2018) during the rehydration of dried amaranth.

Changes in chlorophyll content during storage
Initial chlorophyll content of dried green beans was higher in blanched dried green beans (Table 5). As the days of storage progressed, a significant (P≤0.05) decrease in chlorophyll content of all green bean samples was observed, the decrease in chlorophyll was witnessed in samples packed with LDPE or HDPE. This decrease in chlorophyll content during storage might be due to its oxidation which might have contribution in conversion of chlorophyll to pheophytin (Kalaskar et al., 2012). The similar trend was also reported by Singh and Sagar, (2010); Seevaratnam et al. (2012); Rajeshwari et al. (2013); Pavani and Aduri, (2018). The samples packed in HDPE were found to have significantly (P≤0.05) higher chlorophyll content than samples packed in LDPE which might be due to prevention of conversion of chlorophyll to pheophytin due to its less oxidation as HDPE films have good oxygen barrier properties than LDPE films (Singh and Sagar, 2010). Pavani and Aduri, (2018) also observed the similar pattern of behaviour during storage.

Changes in color values (L* a* b*) during storage
Effect of storage on L* a* and b* values are shown in Table 5. During the storage the color values (L*, a* and b*) in un-blanched as well as blanched dried samples showed decreasing with the storage time. This decrease in lightness and greenness (L* a* b*) could be indicative of pigment oxidation, loss of green color and as a result of browning upon storage. Regarding mode of packaging, HDPE showed high retention of L* a* b* values than LDPE, as HDPE has higher oxygen barrier properties than LDPE which might have contribution in prevention of conversion of chlorophyll to pheophytin due to the pigment oxidation (Singh and Sagar, 2010). These results are also in agreement with findings of Natabirwa et al. (2016) in leafy vegetables.

Conclusion
Three minutes blanching in boiling water caused complete inactivation of peroxidase in green beans. Blanched samples showed shorter drying time than un-blanched samples due to tissue softening resulting in faster moisture removal by enhancing moisture transfer from inside the samples. Loss of mineral due dissolution of minerals during blanching caused slight loss in mineral content of the blanched dried beans than un-blanched samples. Blanching treatment was found to assist in retaining more chlorophyll pigment thus the color of blanched samples was more appealing. The rehydration ratio of dried green bean samples increased from 3.26 to 3.95 (un-blanched dried) and 4.41 to 5.14 (blanched dried) as the drying temperature was increased from 50 to 70 ºC respectively. During the storage of 60 days no change was observed in ash, protein, fat and fiber content of the dried green beans however slight decrease in carbohydrate and chlorophyll content was witnessed possibly due to biochemical degradation with storage time. Rehydration ratio was found to decrease during storage, however decrease in
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**Table 4: Change in proximate composition of dried green beans during storage**

| Parameters | Packaging material | Storage days | **Drying temperatures** | **Un-blanched dried** | **Blanched dried** |
|------------|-------------------|--------------|------------------------|-----------------------|-------------------|
|            |                   |              | 50 °C      | 60 °C      | 70 °C | 50 °C | 60 °C | 70 °C |
| Moisture % | HDPE              | 0            | 14.09±0.00a | 14.00±0.11a | 13.90±0.15a | 14.00±0.11a | 13.96±0.08a | 13.88±0.05a |
|            |                   | 30           | 14.55±0.09d | 14.40±0.09d | 14.23±0.05d | 14.24±0.04d | 14.23±0.05d | 14.16±0.08d |
|            |                   | 60           | 14.85±0.05b | 14.74±0.10b | 14.60±0.10b | 14.60±0.05b | 14.60±0.10b | 14.47±0.13b |
| Ash %      | HDPE              | 0            | 4.87±0.13a  | 4.58±0.11a  | 4.33±0.06a  | 4.41±0.02a  | 4.13±0.04a  | 3.96±0.16a  |
|            |                   | 30           | 4.84±0.12a  | 4.55±0.10a  | 4.28±0.06a  | 4.38±0.04a  | 4.10±0.05a  | 3.93±0.07a  |
|            |                   | 60           | 4.82±0.11a  | 4.53±0.11a  | 4.25±0.07a  | 4.34±0.04a  | 4.07±0.04a  | 3.90±0.08a  |
| Protein %  | HDPE              | 0            | 8.29±0.20a  | 8.25±0.16a  | 8.23±0.10a  | 8.18±0.11a  | 18.15±0.11a | 18.12±0.11a |
|            |                   | 30           | 18.19±0.26a | 18.13±0.24a | 18.16±0.23a | 18.11±0.15a | 18.05±0.26a | 18.09±0.22a |
|            |                   | 60           | 18.09±0.25a | 18.04±0.22a | 18.08±0.25a | 18.03±0.13a | 18.05±0.13a | 18.03±0.24a |
|            | LDPE              | 0            | 18.29±0.20a | 18.25±0.16a | 18.23±0.10a | 18.18±0.11a | 18.15±0.11a | 18.12±0.11a |
|            |                   | 30           | 18.11±0.24a | 18.06±0.21a | 18.11±0.22a | 18.01±0.23a | 18.00±0.24a | 18.00±0.25a |
|            |                   | 60           | 18.05±0.27a | 18.00±0.25a | 18.06±0.20a | 18.00±0.24a | 17.98±0.23a | 17.97±0.22a |
| Fat %      | HDPE              | 0            | 2.07±0.06a  | 2.01±0.05a  | 1.99±0.02a  | 2.06±0.06a  | 1.98±0.03a  | 1.98±0.03a  |
|            |                   | 30           | 2.06±0.06a  | 2.01±0.05a  | 1.96±0.05a  | 2.06±0.06a  | 1.97±0.04a  | 1.96±0.06a  |
|            |                   | 60           | 2.03±0.05a  | 2.00±0.06a  | 1.95±0.04a  | 2.03±0.07a  | 1.97±0.03a  | 1.95±0.05a  |
|            | LDPE              | 0            | 2.07±0.06a  | 2.01±0.05a  | 1.99±0.02a  | 2.06±0.06a  | 1.98±0.03a  | 1.98±0.03a  |
|            |                   | 30           | 2.03±0.05a  | 1.99±0.05a  | 1.95±0.05a  | 2.01±0.09a  | 1.96±0.06a  | 1.95±0.04a  |
|            |                   | 60           | 2.02±0.06a  | 1.97±0.04a  | 1.94±0.04a  | 2.00±0.04a  | 1.96±0.03a  | 1.94±0.04a  |
| Fibre %    | HDPE              | 0            | 15.06±0.11a | 14.90±0.08a | 14.69±0.09a | 14.97±0.10a | 14.77±0.11a | 14.59±0.11a |
|            |                   | 30           | 15.00±0.17a | 14.82±0.15a | 14.65±0.16a | 14.90±0.17a | 14.70±0.17a | 14.52±0.17a |
|            |                   | 60           | 14.96±0.11a | 14.77±0.10a | 14.60±0.09a | 14.87±0.10a | 14.64±0.13a | 14.46±0.12a |
|            | LDPE              | 0            | 15.06±0.11a | 14.90±0.08a | 14.69±0.09a | 14.97±0.10a | 14.77±0.11a | 14.59±0.11a |
|            |                   | 30           | 14.98±0.10a | 14.80±0.17a | 14.59±0.18a | 14.87±0.19a | 14.68±0.18a | 14.47±0.19a |
|            |                   | 60           | 14.95±0.11a | 14.75±0.12a | 14.53±0.15a | 14.95±0.13a | 14.62±0.15a | 14.42±0.15a |
| Carbohydrate% | HDPE              | 0            | 45.62±0.10a | 46.26±0.15a | 46.86±0.11a | 46.38±0.10ab | 47.01±0.12a | 47.47±0.12a |
|            |                   | 30           | 45.36±0.17a | 46.09±0.04b | 46.77±0.05b | 46.31±0.12b | 46.95±0.19b | 47.44±0.10b |
|            |                   | 60           | 45.25±0.11a | 45.92±0.09c | 46.50±0.07d | 46.12±0.09c | 46.79±0.13c | 47.31±0.12c |
|            | LDPE              | 0            | 45.62±0.10a | 46.26±0.10a | 46.86±0.11a | 46.38±0.10ab | 47.01±0.12a | 47.47±0.12a |
|            |                   | 30           | 45.38±0.17b | 45.97±0.18c | 46.68±0.07d | 46.45±0.12a | 47.00±0.12a | 47.39±0.15b |
|            |                   | 60           | 45.27±0.14c | 45.87±0.06d | 46.59±0.18d | 45.97±0.13d | 46.77±0.07c | 47.17±0.07c |

**Notes:** Values with different letters in columns showed statistically significant differences at a 5% level, according to Duncan’s multiple range test.

RR was higher in samples stored LDPE than HDPE, and the differences might be due to difference in moisture barrier properties of the packaging material. The color parameters showed decrease with storage time and no difference in decrease in color parameters was observed in between the two packaging materials. Therefore, it was concluded that blanching of green beans not only affects the color of the green beans but the drying behaviour as well, additionally
Effect of Blanching and Drying Temperatures on Various Physico-chemical Characteristics of Green Beans

| Parameters | Packaging materials | Storage days | Drying temperatures | Un-blanched dried | Blanched dried |
|------------|---------------------|--------------|---------------------|--------------------|----------------|
|            |                     |              | 50 °C | 60 °C | 70 °C | 50 °C | 60 °C | 70 °C |
| Rehydration ratio (g water/g dry matter) |                     | 0        | 2.26±0.10<sup>a</sup> | 2.73±0.05<sup>a</sup> | 2.93±0.04<sup>a</sup> | 3.41±0.10<sup>a</sup> | 3.75±0.08<sup>a</sup> | 4.14±0.09<sup>a</sup> |
|            |                     | 30       | 2.14±0.03<sup>b</sup> | 2.65±0.04<sup>b</sup> | 2.86±0.05<sup>b</sup> | 3.24±0.06<sup>b</sup> | 3.63±0.06<sup>b</sup> | 4.05±0.05<sup>b</sup> |
|            |                     | 60       | 2.04±0.03<sup>c</sup> | 2.54±0.06<sup>c</sup> | 2.76±0.08<sup>c</sup> | 3.15±0.06<sup>c</sup> | 3.54±0.05<sup>c</sup> | 3.96±0.06<sup>c</sup> |
| Total chlorophyll (mg/100g) |                     | 0        | 82.51±0.09<sup>a</sup> | 73.22±0.14<sup>a</sup> | 64.29±0.17<sup>a</sup> | 88.54±0.19<sup>a</sup> | 79.93±0.17<sup>a</sup> | 73.78±0.15<sup>a</sup> |
|            |                     | 30       | 80.28±0.16<sup>b</sup> | 69.58±0.15<sup>b</sup> | 62.54±0.16<sup>b</sup> | 86.97±0.16<sup>b</sup> | 78.57±0.16<sup>b</sup> | 71.64±0.16<sup>b</sup> |
|            |                     | 60       | 78.79±0.15<sup>c</sup> | 67.93±0.17<sup>c</sup> | 61.49±0.14<sup>c</sup> | 84.67±0.18<sup>c</sup> | 76.02±0.14<sup>c</sup> | 70.33±0.18<sup>c</sup> |
| Colour values |                     | 0        | 82.51±0.09<sup>a</sup> | 73.22±0.14<sup>a</sup> | 64.29±0.17<sup>a</sup> | 88.54±0.19<sup>a</sup> | 79.93±0.17<sup>a</sup> | 73.78±0.15<sup>a</sup> |
|            |                     | 30       | 76.94±0.14<sup>d</sup> | 68.17±0.16<sup>d</sup> | 61.33±0.19<sup>d</sup> | 85.30±0.13<sup>d</sup> | 76.37±0.19<sup>d</sup> | 69.45±0.17<sup>d</sup> |
|            |                     | 60       | 76.44±0.16<sup>e</sup> | 65.04±0.14<sup>e</sup> | 59.17±0.18<sup>e</sup> | 83.17±0.18<sup>e</sup> | 73.80±0.15<sup>e</sup> | 68.60±0.15<sup>e</sup> |
| L* value |                     | 0        | 41.76±0.98<sup>a</sup> | 40.08±0.22<sup>a</sup> | 36.66±0.57<sup>a</sup> | 24.90±0.26<sup>a</sup> | 21.94±0.52<sup>a</sup> | 21.02±0.18<sup>a</sup> |
|            |                     | 30       | 36.78±0.39<sup>b</sup> | 36.01±0.28<sup>b</sup> | 35.33±0.38<sup>b</sup> | 23.71±0.47<sup>b</sup> | 20.99±0.39<sup>b</sup> | 20.37±0.18<sup>b</sup> |
|            |                     | 60       | 35.81±0.70<sup>c</sup> | 35.57±0.11<sup>c</sup> | 33.55±0.62<sup>c</sup> | 21.76±0.18<sup>c</sup> | 20.17±0.09<sup>c</sup> | 20.04±0.04<sup>c</sup> |
| a* value |                     | 0        | 41.76±0.98<sup>a</sup> | 40.08±0.22<sup>a</sup> | 36.66±0.57<sup>a</sup> | 24.90±0.96<sup>a</sup> | 21.94±0.52<sup>a</sup> | 21.02±0.18<sup>a</sup> |
|            |                     | 30       | 35.54±0.31<sup>d</sup> | 33.90±0.29<sup>d</sup> | 32.76±0.38<sup>d</sup> | 21.93±0.11<sup>d</sup> | 20.63±0.21<sup>d</sup> | 20.03±0.05<sup>d</sup> |
|            |                     | 60       | 33.07±0.58<sup>e</sup> | 32.99±0.18<sup>e</sup> | 30.14±0.06<sup>e</sup> | 20.22±0.39<sup>e</sup> | 20.00±0.02<sup>e</sup> | 19.94±0.05<sup>e</sup> |
| b* value |                     | 0        | -4.78±0.43<sup>a</sup> | -4.10±0.13<sup>a</sup> | -3.98±0.16<sup>a</sup> | -4.57±0.96<sup>a</sup> | -3.69±0.42<sup>a</sup> | -3.13±0.79<sup>a</sup> |
|            |                     | 30       | -4.20±0.34<sup>c</sup> | -3.83±0.12<sup>c</sup> | -2.63±0.35<sup>c</sup> | -3.48±0.16<sup>c</sup> | -2.22±0.16<sup>c</sup> | -1.66±0.15<sup>c</sup> |
|            |                     | 60       | -3.51±0.15<sup>d</sup> | -2.44±0.12<sup>d</sup> | -2.25±0.12<sup>d</sup> | -2.99±0.11<sup>d</sup> | -1.90±0.26<sup>d</sup> | -1.38±0.19<sup>d</sup> |
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