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EFFECT OF PASSIVE MODIFIED ATMOSPHERE PACKAGING AND PRETREATMENT ON POST HARVEST QUALITY OF GREEN PIGEON PEA KERNELS STORED UNDER AMBIENT CONDITION

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ABSTRACT

Green pigeon pea kernels (GPPK's) are protein rich vegetable. GPPK of BDN-2001-2009 at 70 days of crop maturity was tested to improve shelf-life and reduced browning. 17 treatments of blanching temperature 75, 85, 95°C in combination with 1, 4, 7 min treatment duration and two packaging films polypropylene (PP) and low density polyethylene (LDPE) of 100, 200, 300 gauge were applied. Packets were stored at ambient condition (15-38°C; 19-49% RH). Observations were recorded at 4 days interval till 12th day for physiological loss of weight (PLW), firmness, color deviation, moisture content and sensory status. Experiment was conducted in Box-Behnken model and 17 treatments with 6 categoric factors giving 102 treatment combinations were studied. Optimized independent parameters for modified atmosphere packaging of GPPK by response surface methodology were 93.73°C blanching temperature, 1 min blanching time and 267.64 gauge packets. Predicted responses were 0.87% PLW, 3.83 N firmness, 47.83% color deviation, 61.46% moisture content and sensory status of 8.83. Blanching for 1 min at 95°C and packaging in 300 gauges PP, nearest to optimized treatment was found acceptable by HACCP standards at level-2 for microbial load with headspace composition of 12.9% O_2 and 8.1% CO_2 on 12th day under ambient storage.

INTRODUCTION

Pulses are the major source of protein for vegetarians among Indian population. The per capita availability of protein in the country is 28 g/day, while WHO recommended it should be 80g/day (Saroj *et al.*, 2013). Demand of proteins in daily diet is met out from pulses which are low in quantity. As far as productivity of pulses is concerned, in agricultural production system we have almost reached to maximum level. India produced 17.38 million tonnes of pulses in 2014-2015 (Agricultural Statistics at a Glance, 2015). Pulses are chief and economical source of proteins particularly for vegetarians and for poor because animal proteins are beyond their reach. It is mainly consumed as split pulse as 'dal' or fresh vegetable (de-hulled split peas) in some parts of India such as Gujrat, Maharashtra and Karnataka or as green vegetable in some tribal areas of various states (Balai *et al.*, 2013). There is a large scope for processing pulse as green vegetables like green peas, green gram, green pigeon pea etc. Like green peas (*Pisum sativum*) green pigeon pea kernel (GPPK) is a source of vitamins (A, B complex and C), minerals (Ca, Fe, Zn and Cu), carbohydrates and dietary fiber (Singh *et al.*, 2015). In comparison to green peas, the GPPK has five times more β-carotene content, three times more thiamine, riboflavin and niacin content and double vitamin C content; thus, GPPK is nutritionally rich vegetable for use in daily cuisine. (Saxena *et al.,* 2010).

Food packaging technologies maintain freshness, quality and help a lot in extending shelf life (Day, 1998; Thompson, 1998). The physical shelf life of the packaged product taking into account their fitness for human consumption along with their essential nutrients and bioactive compounds *etc.* can be enhanced by means of suitable packaging technologies such as modified atmosphere packaging (MAP) that has become a widely used food preservation technique, which minimally affects fresh produce characteristics and hence fit in the recent consumer preference for fresh and additives free food (Mangaraj and Goswami, 2009; Mohammed *et al.*, 2015). MAP is being used increasingly for extending shelf life, improving the product image and reducing the wastage of a wide range of fresh fruits and vegetables (Day *et al.*, 2001).

Therefore, this experiment was formulated with an objective to develop a MAP system for GPPK to increase shelf life and to study changes in physico-chemical and textural properties of GPPK under MAP to identify the extent for its suitability of consumption after storage under ambient condition; with an hypothesis that "Minimal processing and modified atmospheric packaging can increase the shelf life and thus availability of green pigeon pea kernels in the areas other than production catchment".

MATERIALS AND METHODS

Material

Green kernels of pigeon pea (*Cajanus cajan*) of promising entry no. BDN-2001-2009 was found superior over four years for vegetable purpose during pigeon pea research experiments at Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India (Annual Report on Pulse Breeding, Pulses Research Unit, Dr. PDKV, Akola, Maharashtra 2012-2015) was procured from University fields. The fresh green pigeon pea was shelled manually. Damaged, under matured and over matured GPPK's, foreign matter was discarded from the lot of shelled kernels and the remaining uniform sized kernels were taken for the experimental purpose (Mali, 2016).

Pre-treatment

The cleaned and graded fresh GPPK's were blanched with solution containing citric acid and potassium meta-bisulphite (KMS) at the rate of 0.24 % each. Three blanching temperatures *i.e.*75ºC, 85ºC and 95ºC was used in combination with 1, 4 and 7 minutes exposure times. Thereafter treatment wise the blanched GPPK's were kept in colander to remove excess water (Nicholas, 1974).

Selection of packaging material

Blanched kernels were packed in polypropylene (PP) and low density polyethylene (LDPE) pouches of size 127×178 mm of various thicknesses viz. 100, 200, 300 gauge each (Ben-Yehoshua, Fishman and Rodov, 1994), heat sealed and placed at ambient conditions (15-38ºC temperature and 19-49 % RH). The sample size was 100 g in each packet (Mali, 2016).

Experimental design and treatment of data

The experiment was conducted by Box-Behnken design and data was subjected to analysis of variance by response surface methodology (RSM). Three variables and three levels including 17 treatments formed by 5 central points were used for analysis. The dependent variables *viz*. physiological loss in weight (PLW), firmness, chlorophyll, color deviation (ΔE), moisture content (% Wb), sensory status and the shelf life of GPPK's was assumed to be affected by three independent variables (factors) *viz*., blanching temperature (A), blanching duration (B) and thickness of packaging material (C) as well as categoric factors *viz*. type of packaging material (PP and LDPE) and ambient storage condition. Using statistical design of Box-Behnken model, 17 treatments multiplied by six categoric factors giving total one hundred and two (102) treatment combinations were tested and RSM was employed to study the effect of factors (process parameters) on responses and accordingly process parameters were optimized (Mali, 2016).

Optimization

Response Surface Methodology (RSM) was applied to the experimental data using the package, Design-Expert version 9.0.6.2 (Stat Ease Inc, Minneapolis, MA Trial version, 2016). Numerical optimization of input parameters was carried out for storage study under ambient condition (Mali, 2016).

Quality parameters

Physilogical loss in weight (PLW)

The weight loss of GPPK's packed in Poly Propylene (PP) and Low Density Poly Ethylene (LDPE) polymeric package under MAP was determined by weighing the individual packet initially and on 12th day of observation using a laboratory level weighing balance (Model CT-300, Contech Make, India) having least count of 0.001g (Ranganna, 1995).

$$PLW(\%) = (\frac{\text{Initial weight - Final Weight}}{\text{Initial Weight}}) \times 100$$

Firmness

Texture was determined as firmness / hardness. The fresh GPPK's are tender and, as they dry out they become hard. As the experiment was done for MAP of the kernels, it was expected the kernels should maintain the fresh, tenderness characteristics. Texture analysis was done on 10 fresh GPPK's from each treatment. The force necessary to compress the GPPK's was measured using Texture Analyzer-Stable Micro System Model TA-HD Plus, Hamilton, MA (Szisesnaik, 1963; Brown, 1967 and Ranganna, 1995).

Color measurement

Change in color indicates the freshness and quality of GPPK's while storage and may be used as a parameter for analysis. Colour of the fresh GPPK's was measured using a Colorimeter (Model CR-410, Konika Minolta Make, USA). On each day of interval of storage, the 'L', 'a' and 'b' values were noted. Colour of GPPK's was measured to calculate the change in colour after storage under ambient condition. Colour deviation is calculated by using formula (Ranganna, 1995) -

$$\Delta E = \text{Colour Deviation} = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2} \qquad (2)$$

Here, L = lightness ($\Delta L = L_2 - L_1$ = Final value – initial value);

a = red-green axis ($\Delta a = a_2 - a_1$ = Final value – initial value); and

b = yellow-blue axis ($\Delta b = b_2 - b_1$ = Final value – initial value)

Moisture content

The moisture content of fresh GPPK's was determined by using the hot air oven (Swastik, Scientific Instruments Pvt. Ltd. make, India), which has a thermostat to control the temperature and its operating temperature range between 0ºC to 100ºC. The flat metallic plate of known weight was taken. Nearly 15 g sample was spread on the dish. The weight of sample plus dish was noted. The hot air oven was maintained at 100ºC. The samples were heated at this temperature for 16-18 hr. The sample was reweighed and the initial moisture content was determined by the following formula (Ranganna, 1995).

$$\text{Moisture content}(\%) = (\frac{\text{Initial Weight of sample - Final Weight of sample}}{\text{Intial Weight of sample}}) \times 100$$

Sensory evaluation

To ascertain sensory status, samples were evaluated for overall visual quality, color, odor, texture, taste and overall acceptance using a 9-point hedonic scale with 10 trained panelists. For product attributes and acceptance, scores above 5 were considered acceptable (Ranganna, 1995).

Headspace gaseous composition

The in-pack gaseous composition of GPPK's was measured as per the method adopted by Singh *et al*. (2014). A single hole covered with silicon septum was made in polymeric package for measurement of gas concentrations directly with gas analyzer (Model 902 D, DualTrak O_2/CO_2 Analyzer, USA) at each day and O_2/CO_2 composition was recorded.

Microbial analysis

The microbial profile of GPPK's on 12th day of storage was studied by standard plate count method in completely randomized design. One gram of sample was taken for microbial analysis. Serially diluted samples (1.0 ml) were spread plated on Potato Dextrose Agar and Nutrient agar to determine fungi and bacteria, respectively. The plates were incubated, observations recorded and results are expressed as colony forming units (CFU) per gram of sample (Charpe *et al.*, 2016). The data was subjected to statistical analysis using software Web Agri Stat Package - 1 (WASP-1). (http://www.ccari.res.in)

RESULTS AND DISCUSSION

This is a unique work as for the first time under ambient condition any effort for preservation of green pigeon pea kernels has been made and hence discussion is done logically and appropriate references are provided where they are available.

Physiological loss of weight (PLW)

The variation in PLW in different treatments kept for storage study under ambient condition at the end of 12th day was found to be minimum (0.87 %) for treatment having the blanching for 1 min. at 75ºC temperature and packaging in LDPE pouches of 200 gauge thickness and it was found to be maximum (3.411 %) in case of treatment having the blanching for 1 min at 85ºC temperature and packaging in PP pouches of 100 gauge thickness.

From Fig.1 (A&B) it is evident that PLW was the least at low temperature and duration. PLW increased with increase in temperature and duration up to certain level, after which PLW decreased when temperature and duration increased. It also shows that there was no much effect of variation in thickness of packaging material. Although, PLW was observed to be increasing with the duration of blanching for first five minutes, thereafter, it showed decreasing trend. The results confirm the findings of Drake *et al.* (1981), Jowitt *et al.* (1987) and Jayas and Jeyamkondan (2002) those reported loss in physiological weight under storage.

Firmness

The firmness in the treatments kept for storage study under ambient condition at the end of 12th day was found to be minimum (3N) for treatment having the blanching for 1 min at 85ºC temperature and packaging in LDPE pouches of 300 gauge thickness and it was found to be maximum (4.3N) in case of treatment having the blanching for 1 min at 75ºC

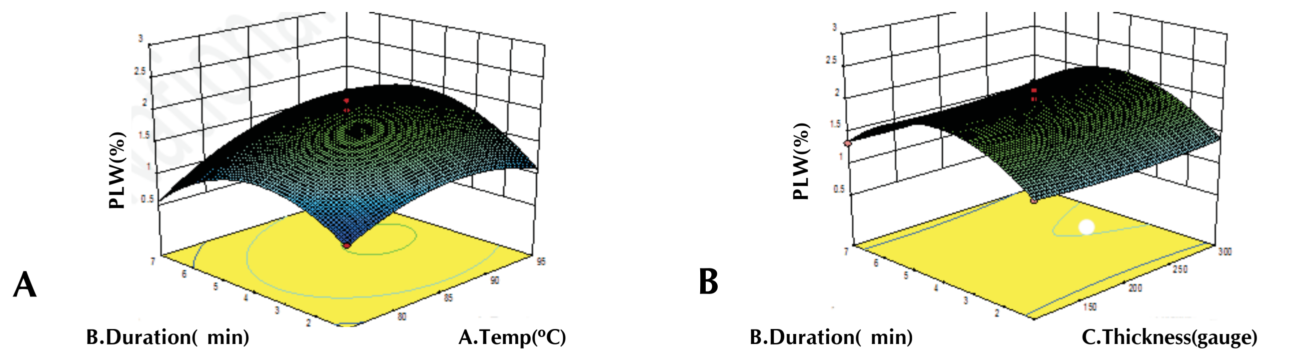

Figure 1 (A&B) : Effect of blanching temperature, blanching duration and thickness of packaging material on PLW of GPPK's stored under ambient condition

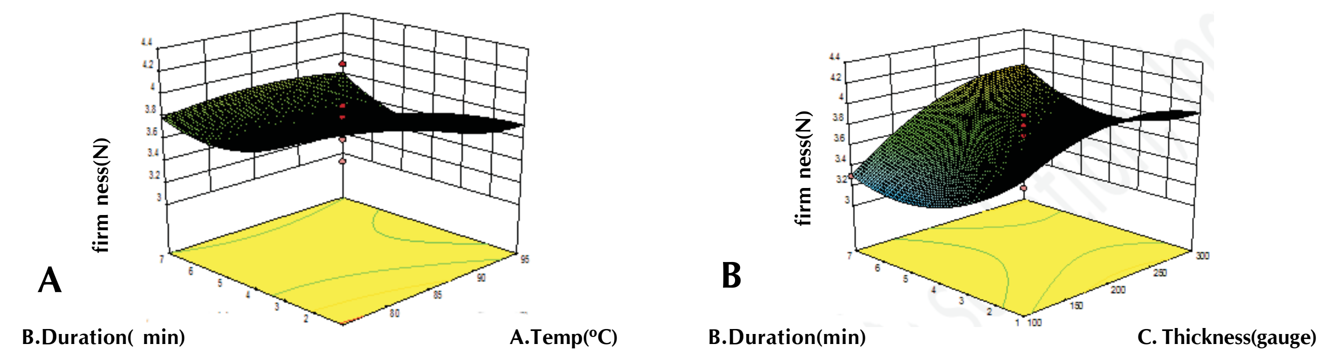

Figure 2 (A&B): Effect of blanching temperature, blanching duration and thickness of packaging material on firmness of GPPK's stored under ambient condition

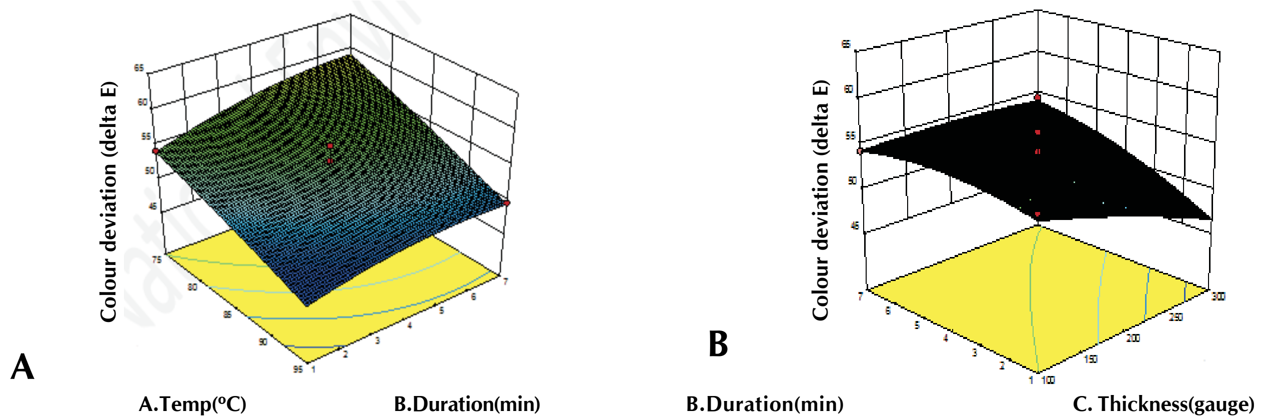

Figure 3 (A&B): Effect of blanching temperature, blanching duration and thickness of packaging material on color deviation of GPPK's stored under ambient condition

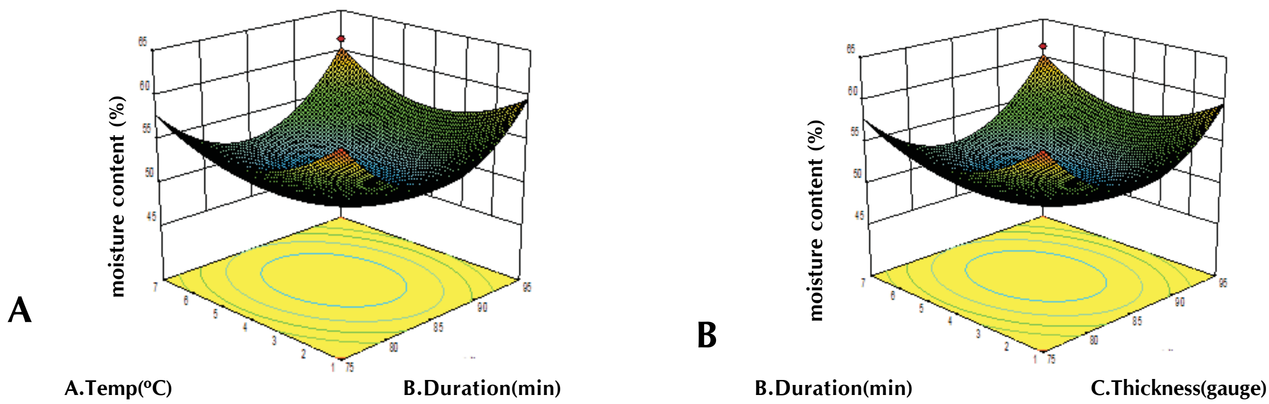

Figure 4 (A&B): Effect of blanching temperature, blanching duration and thickness of packaging material on moisture content of GPPK's stored under ambient condition

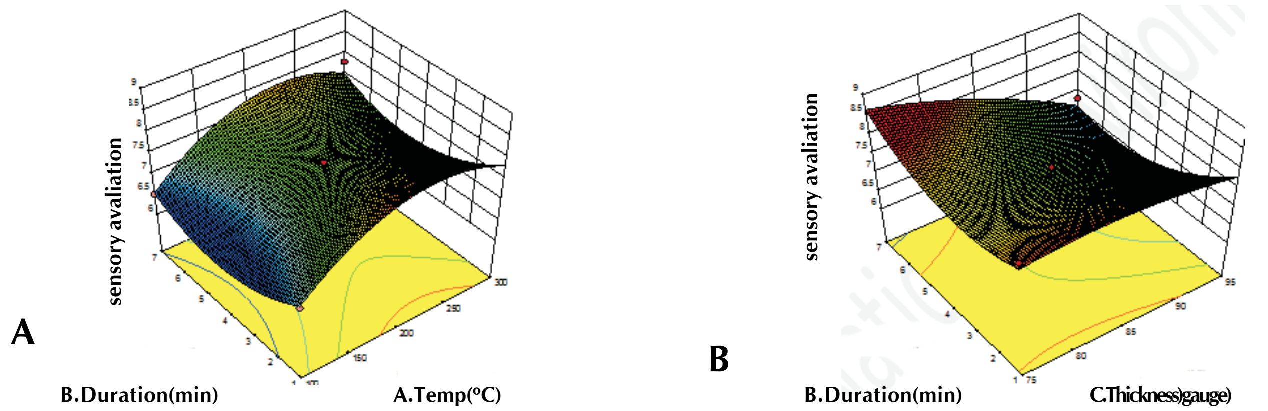

Figure 5 (A&B): Effect of blanching temperature, blanching duration and thickness of packaging material on sensory status of GPPK's stored under ambient condition

temperature and packaging in LDPE pouches of 200 gauge thickness.

From Fig.2 (A&B), it is evident that firmness varies with duration of blanching. Initially firmness was the maximum. Upto certain level firmness decreased and again increased slightly with increase in duration of blanching. Inverse trend was observed with respect to temperature of blanching. It is also revealed that firmness increases with increase in thickness of packaging material upto certain level. After certain point firmness decreased slightly as thickness of packaging material increased further.

This may be due to the fact that at low blanching temperature due to the evaporation loss of moisture and thus resultant shrinkage of GPPK's is minimum, Therefore, the blanching at minimum temperature for low duration along with the higher thickness of packaging material that reduces the respiration

Table 1: Optimization constraints for different variables and responses for GPPK's stored under ambient condition

Name	Goal	Lower Limit	Upper Limit
Blanching temperature (°C)	is in range	75	95
Blanching duration (min)	is in range	1	7
Thickness of packaging material (gauge)	is in range	100	300
Type of bag	is in range	PP of D	LDPE of D
PLW (%)	Minimize	0.899	2.956
Firmness (N)	Maximize	3	4.3
Chlorophyll (%)	Maximize	14.85	20.1
Color deviation (delta E)	Minimize	46.25	63.54
Moisture content (%)	Maximize	47.55	61.46
Sensory evaluation	Maximize	6.4	8.2

Thus the optimized packaging conditions for best shelf life of GPPK's under ambient condition are - 1)Blanching temperature (°C) : 95;2)Blanching duration (min) :1;3)Thickness of packaging material (gauge) : 300 (PP)

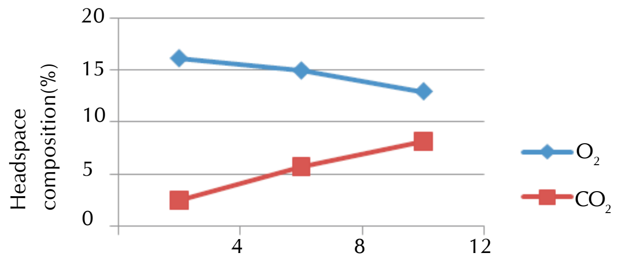

Fig 6: Variation in headspace gaseous composition of GPPK packets stored under ambient condition

loss higher firmness of GPPK's is obtained. Loss of firmness has been earlier observed by Gangwar (1972) in ripe fruits and by Singh *et al.* (2014) in chick pea sprouts.

Color deviation

The variation in color in different treatments kept for storage study under ambient condition at the end of 12th day was found to be minimum (46.25%) for treatment having the blanching for 7 min at 95°C temperature and packaging in PP pouches of 200 gauge thickness and it was found to be maximum (63.54%) in case of treatment having the blanching for 4 min at 75°C temperature and packaging in PP pouches of 100 gauge thickness.

From Fig.3 (A&B), it is evident that color deviation decreased with increase in temperature and decrease in duration of blanching. It also showed that color deviation decreased with increase in thickness of packaging material. These results are supported by the findings that the citric acid curtails activity of enzyme polyphenol oxidase, thus, reducing the browning of shelled GPPK's due to phenol synthesis (Macheix *et al.*, 1990).

Moisture content

Moisture content at the end of 12th day in the treatments stored under ambient condition was found to be minimum (47.55%) for treatment having the blanching for 4 min at 85°C temperature and packaging in LDPE pouches of 200 gauge thickness and it was found to be maximum (61.88%) in case of treatment having the blanching for 4 min at 95°C temperature and packaging in PP pouches of 100 gauge thickness.

From Fig.4 (A&B), it is evident that initially moisture content was high at low temperature and low duration of blanching. As temperature and duration of blanching increased upto certain level, moisture content decreased and then again moisture content increased as temperature and duration of blanching increased. This may be due to the fact that at low temperature with less exposure time evaporation losses are less; these increases due to increase in temperature and exposure to certain extent due to increasing evaporation losses (Jowitt *et al.*, 1987). Thereafter it decreases due to intake of moisture by the kernels. It also shows that moisture content increased with increase in thickness of packaging material. This may be due to the fact that at ambient condition there is high rate of respiration and hence GPPK's packed in higher thickness of packaging material shows maximum moisture content as high thickness allows minimum permeability for transmission of gases as explained by Rai *et al.* (2002).

Sensory evaluation

The sensory status of the treatments was found to be minimum (6.4) for treatment having the blanching for 4 min at 75°C temperature and packaging in PP pouches of 300 gauge thickness and it was found to be maximum (8.2) in case of treatment having the blanching for 1 min at 75°C temperature and packaging in LDPE pouches of 200 gauge thickness.

From Fig 5 (A&B), it is evident that sensory status decreased with increase in blanching temperature and increased with increase in blanching duration and thickness of packaging material. It may be due to the fact that higher temperature causes loss of aroma (Kader *et al.*, 1989 and Carla Barbosa *et al.*, 2015) whereas prolonged exposure at low temperature results into partial cooking of grains thus increasing aroma. Further packaging in thicker packaging material retains the developed aroma. Similar results were obtained by Kenawi *et al.* (1992) when they studied the effect of packaging materials and storage conditions on vitamin C retention in green pepper, spinach and guava.

Optimization of independent variables for GPPK's stored under ambient condition

For numerical optimization desired goals for each factor and responses were chosen as shown in Table 1. On the basis of numerical optimization the combination having the maximum desirability value 0.93 selected as the optimum condition for MAP of GPPK's under ambient condition was blanching temperature 93.73°C, blanching duration 1 min and thickness of packaging material 267.64 gauge in which 0.87% physiological weight loss, 3.83 N firmness, 47.83% color deviation, 61.46% moisture content and sensory status of 8.38 was obtained.

Headspace gaseous composition

The variation in headspace gaseous composition, (O_2 and CO_2 %) of GPPK packets from the first interval day to 12th day of the treatment (95°C for 1 min and 300 gauge of PP material) nearest to optimized treatment (93.73°C for 1 min and 267.64

gauge of PP) kept for storage study under ambient condition is presented in Fig. 6.

The headspace gaseous composition of the sample blanched at 95ºC for 1 min and packed in 300 gauge polypropylene which was treatment nearest to the optimized treatment (93.73ºC for 1 min and packed in 267.64 gauge of PP material) shows that, O_2 composition was found to be decreased from 20.95% to 12.9% and CO_2 composition was found to be increased from 0.003% to 8.1% as storage period increased up to 12 days under ambient condition. These results are in accordance with the findings of Kader (1987), Fonseca *et al*. (2002), Ho and Young (2004) and Finnegan *et al*. (2013) where they recorded increase in CO_2 level with decrease in O_2 level under storage.

Microbial load

Data generated through the microbial analysis of GPPK's by standard plate count method was subjected to statistical analysis using software Web Agri Stat Package - 1 (WASP-1). The bacterial load of GPPK's stored under ambient condition was observed to be minimum (2.33×10^4 cfu/gm) and significantly superior over other treatments in the treatment 95°C for 1 min and 300 gauge of PP material on 12th day of storage. The fungal load of GPPK's stored under ambient condition was observed to be minimum (0.67×10^4 cfu/gm) and significantly superior over other treatments in the treatment 95°C for 1 min and 300 gauge of PP material. On the basis of quality parameters as well as microbial count blanching of the GPPK's in 0.24% citric acid with 0.24% KMS solution at 95°C for 1 min and packaging in polypropylene bags of 300 gauge thickness was the most suitable for preserving GPPK's under ambient condition. Being a commodity it is necessary that the microbial load in packaged GPPK's should be less than the threshold level as per the safety standards (Snyder, 2003). In current findings, microbial load of packaged GPPK's in optimized conditions are found to be less than the threshold level set for the microbial safety of minimally processed vegetables (Rajkowski and Baldwin, 2003)

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