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Application of Multi-Hurdles Technology in Development and Quality Evaluation of Shelf-Stable Barbecued Chicken Stored at Ambient Temperature

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A B S T R A C T

The study was carried out to develop the shelf stable barbecued chicken treated with multi-hurdles, humectant (HG) - Glycerol, acidulants (AL) *viz.* lactic acid (LA) and glucono-delta-lactone (GDL) and irradiation and to compared the shelf life at ambient temperature of the vacuum packed developed product with that of control. In experiment there were four different combinations used i.e. C_1-Control 1 (without hurdles), C_2-Control 2 (2% HG), T_1-(C_2 + 0.2%LA + 0.2%GDL + Non-irradiated) and T_2-(C_2 + 0.2%LA + 0.2%GDL + Irradiated). Physico-chemical, microbiological and sensory characteristics were analyzed at 3 days intervals upto 6 days of storage period. The pH value of all the samples significantly increased during storage period. No significant changes were observed in a_w of controls and treatment samples during storage. All the barbecued chickens tended a significant decrease in the L* value on day 3 of storage. The a* value increased in all the samples during storage. The product treated with hurdles like HG along with AL tended a significant (P<0.05) decrease in the b* values on day 3 of storage. TBARS and tyrosine values were significantly increased throughout the storage period, but were below the acceptable limits for control and shelf stable barbecued chicken. For total viable and yeast and mold counts, significantly (P<0.05) lower count was noted in irradiated sample during storage period. However, irradiated sample exhibited off-odour during sensory evaluation from day of irradiation and it became very intense on sixth day of storage. From the above studies it can be inferred that SBC incorporated with HG and AL had a shelf-life upto 3 days at ambient temperature storage and was comparable with control for sensory attributes and can be marketed without any cold chain upto 3 days.

Introduction

India has largest livestock resources, among which poultry broiler production has been more vibrant than layer production within the poultry sector, with an annual growth rate of 11.44 per cent, production of 3.72 million tonnes and employment for 4.29 million people (Index, 2015). In worldwide chicken based meat products are more preferred by the peoples and also demand for the processed chicken meat products is ever increasing due

to urbanization, improved standards of living and changing life styles. However, impairment of progress of processed meat sector is due to inadequate processing technology and lack of cold chain facilities for effective marketing. In foods, hurdles are processes or substances inhibiting deteriorative changes. The method of improving the microbial stability and the sensory quality of the shelf-stable foods as well as their nutritional and economic properties by the use of two or more hurdles is called hurdle technology (HT) (Leistner *et al.*, 1980 and Brimelow, 1985). The main objective of the hurdle technology is to prevent the food poisoning and microbial spoilage by application of several hurdles, minimally in optimum combination, thereby contributing for improvement of product safety, sensory qualities, stability of the product, as well as saving of energy (Das and Radhakrishna, 2001). Shelf stable meat products could be processed by adjusting hurdles like water activity (aw), pH, creating anaerobic conditions and using food preservatives *etc.* and can be stored without refrigeration (Leistner and Rodel, 1976 and Alakomi *et al.*, 2002). Barbecued chicken is popular and versatile meat product with greater acceptability all over the world and it's being perishable, generally marketed as fresh prepared product. Decreasing the energy requirement for food preservation and improving the safety of preserved foods are the two factors to be addressed, especially in India where there is acute shortage of power. So study was undertaken to develop shelf-stable, safe and well acceptable barbecued chicken that can be stored at ambient temperature for better distribution and marketing using the hurdle technology or combined processes.

Raw materials

Broiler chicken of 1.5 to 1.8 kg live body weight procured from the local market were humanely slaughtered and dressed under hygienic conditions at Meat Technology Unit, Mannuthy was used for the study. Refined sunflower oil (Sundrop) was used for frying of spice mix. The condiment mixture was prepared as and when required by blending chopped onion, ginger and garlic (1:1:1 w/w) to the consistency of a fine paste. The spice mix used in the experiment was prepared as per the formulation developed in Meat technology unit. Food grade glycerol, lactic acid and glucono-delta-lactone purchased from the Genesys Inc. Tamil Nadu and Roquette Riddhi Siddhi Pvt. Ltd. Mumbai, India was used as acidulants (Table 1).

Preparation of curing solution

The curing solution was prepared by dissolving the curing ingredients at the following concentrations; sodium chloride 3.8%, sodium-tri-polyphosphate 3% and sodium nitrite 900 ppm in high purity cold water. The strength of the brine was maintained 24^0 and it was recorded by using salinometer (Tel-Tru, Tamil Nadu, India).

Preparation of humectant solution and acidulants

Based on experimental design three different levels of Glycerol (HG), *viz.*, 1.0, 2.0 and 3.0 per cent of green weight of the dressed chicken carcasses was weighed and dissolved in cold water (chicken: cold water=1:1.5) for desorption. Based on green weight of the carcasses acidulants were accurately weighed and diluted/mixed with 50 ml distilled water for injection curing.

Vacuum packaging

After cooking and cooling to ambient temperature the barbecued chicken were vacuum packed in PE/Al/PA laminated pouches by using a single chamber vacuum

packaging machine (Sevana, Kochi) and kept at room temperature for physico-chemical and sensory evaluation.

Irradiation

Vacuum packaged samples were subjected to gamma irradiation at 2.5 kGy at melting ice temperature using Gamma Chamber 5000, (BRIT-DAE, Mumbai) where ^{60}Cobalt is utilized as source of irradiation. The non-irradiated samples were designated as control C, irradiated treatment sample as T_2-IR and non-irradiated treatment sample as T_1-NIR.

Physico-chemical attributes

pH

The pH of the cooked barbecued chicken from all the treatments and control were determined by digital pH meter (µ pH system 362, Systronics, India) as per procedure of Troutt *et al.,* (1992).

Water activity (a_w)

For determination of a_w, the samples were cut into small pieces and filled in the sample cup up to the mark. The filled sample cup was kept in the measurement chamber of Lab swift a_w meter (Novasina, Switzerland). The readings were taken, when the stable a_w was on in the display.

$L^* a^* b^*$

Colour of the shelf stable barbecued chicken sample was determined objectively as per Navneet and Shitij (2011) using Hunter Lab Mini Scan XE Plus Spectrophotometer (Hunter Lab, Virginia, USA) with diffuse illumination. The instrument was standardized to measure L^*, a^* and b^* using illuminant 45/0 and 10º standard observer with an aperture size of 2.54 cm. It was calibrated using black and white tiles. Colorimeter score was recorded where 'L' of black equaled 0 and 'L' of white equaled 100, 'a' of lower numbers indicated more green (less red) and higher numbers indicated more red (less green), and 'b' of lower numbers indicated more blue (less yellow) and higher numbers indicated yellow (less blue).

Thiobarbituric acid reactive substances

Thiobarbituric Acid Reactive Substances (TBARS) value in shelf stable barbecued chicken was determined by the extraction method of Witte *et al.,* (1970) with slight modification as extraction supernatant was centrifuged (Eltek Research centrifuge TC 8100) at 6000 rpm for 5 min instead of filtration. The absorbance was measured at 530nm (Systronics-119, UV-visible spectrophotometer, Ahmedabad, India) against blank containing 5ml of distilled water and 5ml TBA reagent. TBARS value, expressed as mg malonaldehyde per kg of barbecued chicken was calculated by multiplying the absorbance with a factor 5.2 (Sathu, 2014).

Tyrosine Value (TV)

The Tyrosine Values of the samples were estimated as per the method described by Pearson (1968).

Microbiological quality

For of estimation of the total viable count (TVC) of the aerobic bacteria, yeast and mold in shelf stable barbecued chicken, the samples were homogenized with peptone water in a Stomacher (Seward Stomacher 400 Circulator).

Total Viable Count (TVC)

Total viable count of aerobic bacteria of each sample was estimated by pour plate method,

as described by Mortan (2001). Using Standard Plate Count Agar (Hi-Media, Mumbai) and incubated at 37°C for 24 h and the count expressed as $\log_{10}$ cfu/g.

Yeast and mold count

Method described by Beuchat and Cousin (2001) was followed for the estimation of yeast and mold count per gram of the sample. Potato Dextrose Agar (Hi-Media, Mumbai) was used. The plates were incubated at 25-27^{o}C for 3 days and the count expressed as $\log_{10}$ cfu/g.

Sensory evaluation

Sensory attributes of the shelf stable barbecued chicken were assessed organoleptically using 8-point Hedonic scale (AMSA, 1983) with the help of seven semi-trained taste panelists drawn from the Department of Livestock Products Technology, Mannuthy, Thrissur. The barbecued chicken was reheated at oven temperature of 100°C for 20 min and then served warm to the panelists with random three-digit code numbers to the samples. The average of the individual scores was taken as the score for the particular attribute.

Statistical analysis

The experiment was replicated four times and the data obtained for physico-chemical and sensory evaluations of different products were statistically analyzed as per Snedecor and Cochran (1994) using SPSS software version 24.

Results and Discussion

Physico-chemical characteristic

The control barbecued chickens C_1 and C_2 and the standardized products, non- irradiated (T_1-NIR) and irradiated (T_8-IR), were vacuum packed in PE/Al/PA laminated pouches and stored at ambient temperature for storage studies. The products were evaluated on 0, 3 and 6th day of preparation and packaging.

pH

The pH of the control C_1 and T_2-IR increased significantly ($p<0.05$) on day 3 of storage. Significantly ($p<0.05$) higher pH value was noted in controls (6.05-6.19) compared to treatments (5.65-5.82) during storage period (Table 2). This may be due to comparatively more accumulation of acidic metabolites due to protein degradation in control by the action of microbes (Bell and Shelef, 1978; Lawrie, 1998). The similar results were reported by Karthikeyan *et al.,* (2000) in *Caprine* keema stored at ambient temperature and Smaoui *et al.,* (2011) in marinated chicken thighs.

Water activity

The a_w of the control C_1 during the storage period was significantly ($p<0.05$) higher than the treatments T_1-NIR and T_2-IR. This might be due to action of HG added in desorption solution of the treatment samples. No significant difference was noted between controls and treatments with the progress of storage period. The observation was in consistent with report of Malik and Sharma (2011) in shelf stable buffalo meat chunks.

Colour

The results with respect to changes in L*a*b* values of the controls and the treatments are shown in the Table 3. All the barbecued chickens tend to have significant ($p<0.05$) decrease in the L* value on day 3 of storage. L* value of T_8-IR was significantly ($p<0.05$) highest and lowest value was observed for control C_1 on day 3 of storage. A non-significant increase in the redness value was

noted in all samples during storage and exceptionally in T_8-IR, a* value significantly ($p<0.05$) increased from 18.88-20.66. The product treated with hurdles like HG along with AL (T_1-NIR and T_2-IR) showed a significant ($p<0.05$) decrease in the b* values on day 3 of storage. Maca *et al.,* (1999) reported an increase in a* and decrease in b* value during storage in the vacuum packaged meat products which may be due to effect of pH on conversion of myoglobin to metmyoglobin. However, Bloukas *et al.,* (1977) reported that in vacuum packaged low fat frankfurters added with two per cent LA, no variation in the colour values were noticed.

Thio Barbituric Acid Reacting Substances (TBARS)

The oxidative stability of the meat products is estimated in terms of TBARS value. The significant increases in the TBARS value in all the samples were found with advancement of storage period (Table 4). The TBARS value of the control barbecued chicken C_1 and C_2 increased from 0.44-0.61, 0.25-0.50, respectively and for treatments T_1-NIR and T_2-IR increased from 0.56-0.68, 0.30-0.53, respectively. Among treatments, irradiated sample had significantly ($p<0.05$) lower TBARS value than non-irradiated sample throughout storage period, this observation was in consistent with finding of Jayathilakan *et al.,* (2009) who reported that incorporation of 2 per cent LA followed by 2 kGy irradiation had a significant ($p<0.05$) effect in inhibiting the rancidity in chicken leg. However, Formanes *et al.,* (2003) and Kanatt *et al.,* (2005) reported that irradiation increases the TBARS value in food products due to autoxidation of fat by formation of free radicals during irradiation. Control C_2 had significantly ($p<0.05$) lower value among all throughout the storage period. Similar observation was noted by Singh *et al.,* (2014) in glycerol added chicken lollipop. The threshold value of TBA is 1.0-2.0 mg malonaldehyde/kg of meat and meat products (Watt, 1962). However, the extend of increase in the TBARS values during storage for three days at ambient temperature was within the acceptable limits in all samples. The results obtained in present study were in accordance with results obtained by Ravi *et al.,* (2014) in irradiated chicken emulsion.

Tyrosine value

The tyrosine value was significantly ($p<0.05$) lower for the barbecued chickens treated with hurdles on the day of processing. On day 3 tyrosine values of all the samples significantly ($p<0.05$) increased, it was more pronounced in controls compared to treatments.

An increase in tyrosine value was reported by Narahari and Suba (2005), Karthikeyan *et al.,* (2000) and Thomas *et al.,* (2007) in shelf stable chicken patties and fry, *Caprine* keema and shelf stable pork sausages, respectively during storage at ambient temperature.

Microbiological quality

For assessing the microbiological changes in the vacuum packed barbecued chicken C_1, C_2, T_2-NIR and T_2-IR, the total viable count (TVC), Yeast and mold counts were noted on 0, 3 and 6^{th} day of storage at ambient temperature in both controls and in two treatments T_1-NIR (non-irradiated) and T_2-IR (irradiated). The results are presented in the Table 5.

The TVC and Yeast and mold counts were significantly ($p<0.05$) increased in all the samples during the storage period and the increase was significantly ($p<0.05$) more pronounced in the control C_1 than treatments incorporated with different hurdles. Irradiation of T_2-IR resulted in a further reduction in TVC and Yeast and mold counts.

Table.1 Formulary for the preparation of barbecued chicken

Ingredients	C_1 (%)	C_2 (%)	T_1 (%)	T_2 (%)
Chicken	100	100	100	100
Glycerol (green wt. of the meat)	--	2	--	--
Lactic acid + Glucono-Delta-Lactone (green wt. of the meat)	--	--	0.2+0.2	0.2+0.2
Coriander powder	1	1	1	1
Small onion	1	1	1	1
Garlic	1	1	1	1
Ginger	1	1	1	1
Lemon juice	1	1	1	1
Kashmiri chilli powder	1	1	1	1
Turmeric powder	0.5	0.5	0.5	0.5
Chilli powder	0.5	0.5	0.5	0.5
Black pepper powder	0.3	0.3	0.3	0.3
Cumin powder	0.2	0.2	0.2	0.2
Cinnamon + Clove powder	0.2	0.2	0.2	0.2
Oregano powder	0.01	0.01	0.01	0.01
Cardamon powder	0.01	0.01	0.01	0.01
Salt (green wt. of the meat)	1.1	1.1	1.1	1.1
Curd	2	2	2	2

*above the quantity of the formulation added over and above treatment (control) barbecued chicken.
C_1-Control-1 (Without hurdles), C_2-Control 2 (2% HG), T_1- (C_2 + 0.2% LA + 0.2% GDL + Non-irradiated), T_2-(C_2 + 0.2% LA + 0.2% GDL + Irradiated) and HG-Humectant, LA- Lactic acid, GDL- Glucono-Delta-Lactone

Table.2 Effect of storage on physico-chemical characteristics of the shelf stable barbecued chicken

Samples	Storage period (days)		
	0	3	6
pH			
C_1	6.08 ± 0.01^{bA}	6.19 ± 0.01^{bB}	Blown
C_2	6.05 ± 0.01^{b}	6.10 ± 0.02^{b}	Blown
T_1	5.65 ± 0.07^{a}	5.82 ± 0.07^{a}	Blown
T_2	5.69 ± 0.03^{aA}	5.81 ± 0.01^{aB}	Off-odour
Water activity (a_w)			
C_1	0.84 ± 0.00^{b}	0.84 ± 0.01^{b}	Blown
C_2	0.81 ± 0.01^{a}	0.83 ± 0.00^{b}	Blown
T_1	0.79 ± 0.01^{a}	0.81 ± 0.00^{a}	Blown
T_2	0.79 ± 0.01^{a}	0.80 ± 0.00^{a}	Off-odour

Means ± SE with different uppercase superscripts in the same row and lowercase superscripts in the same columns are significantly different ($P<0.05$). C_1-Control-1 (Without hurdles), C_2-Control 2 (2% HG), T_1- (C_2 + 0.2% LA + 0.2% GDL + Non-irradiated), T_2-(C_2 + 0.2% LA + 0.2% GDL + Irradiated) and HG-Humectant, LA- Lactic acid, GDL- Glucono-Delta-Lactone (n=6)

Table.3 Effect of storage on the colour (L* a* b*) of shelf stable barbecued chicken

Samples	Storage period (days)		
	0	3	6
L*			
C_1	34.76±1.25^{A}	30.73±0.46^{aB}	Blown
C_2	34.97±0.82^{A}	32.42±0.49^{abB}	Blown
T_1	34.48±0.80^{A}	31.99±0.70^{aB}	Blown
T_2	37.03±0.36^{A}	34.05±0.61^{bB}	Off-odour
a*			
C_1	18.75±0.23	19.40±0.31	Blown
C_2	19.51±0.59	20.49±0.73	Blown
T_1	19.00±0.53	20.34±0.67	Blown
T_2	18.88±0.44^{A}	20.66±0.55^{B}	Off-odour
Hunter b*			
C_1	28.72±0.46^{a}	28.91±0.52	Blown
C_2	29.78±0.40^{a}	29.93±0.61	Blown
T_1	31.08±0.33^{aA}	29.60±0.32^{B}	Blown
T_2	31.14±0.41^{bA}	29.39±0.54^{B}	Off-odour

Means ± SE with different uppercase superscripts in the same row and lowercase superscripts in the same columns are significantly different (P<0.05). C_1-Control-1 (Without hurdles), C_2-Control 2 (2% HG), T_1- (C_2 + 0.2% LA + 0.2% GDL + Non-irradiated), T_2-(C_2 + 0.2% LA + 0.2% GDL + Irradiated) and HG-Humectant, LA- Lactic acid, GDL- Glucono-Delta-Lactone (n=6)

Table.4 Effect of storage on TBARS and Tyrosine value of the shelf stable barbecued chicken

Samples	Storage period (days)		
	0	3	6
TBARS (mg of malonaldehyde/kg)			
C_1	0.44±0.02^{bA}	0.61±0.01^{bB}	Blown
C_2	0.25±0.02^{aA}	0.50±0.01^{aB}	Blown
T_1	0.56±0.02^{cA}	0.68±0.03^{cB}	Blown
T_2	0.30±0.03^{aA}	0.53±0.01^{aB}	Off-odour
Tyrosine (mg/100g)			
C_1	7.24±0.09^{bA}	8.34±0.13^{bB}	Blown
C_2	7.17±0.22^{bA}	8.60±0.12^{bB}	Blown
T_1	6.63±0.12^{aA}	7.78±0.13^{aB}	Blown
T_2	6.36±0.09^{aA}	7.86±0.05^{aB}	Off-odour

Means ± SE with different uppercase superscripts in the same row and lowercase superscripts in the same columns are significantly different (P<0.05). C_1-Control-1 (Without hurdles), C_2-Control 2 (2% HG), T_1- (C_2 + 0.2% LA + 0.2% GDL + Non-irradiated), T_2-(C_2 + 0.2% LA + 0.2% GDL + Irradiated) and HG-Humectant, LA- Lactic acid, GDL- Glucono-Delta-Lactone (n=6)

Table.5 Effect of storage on microbiological quality of shelf stable barbecued chicken

Storage period (days)			
Samples	0	3	6
TVC (log_{10} cfu/g)			
C_1	2.50 ± 0.08^{cA}	6.25 ± 0.28^{cB}	Blown
C_2	2.90 ± 0.07^{bA}	6.33 ± 0.24^{cB}	Blown
T_1	2.14 ± 0.05^{bA}	4.88 ± 0.20^{bB}	Blown
T_2	1.81 ± 0.09^{aA}	3.11 ± 0.04^{aB}	Off-odour
Yeast and mold (log_{10} cfu/g)			
C_1	1.96 ± 0.12^{bA}	2.93 ± 0.19^{bB}	Blown
C_2	1.77 ± 0.14^{bA}	2.78 ± 0.13^{bB}	Blown
T_1	1.76 ± 0.11^{bA}	3.27 ± 0.28^{bB}	Blown
T_2	0.97 ± 0.04^{aA}	2.01 ± 0.06^{aB}	Off-odour

Means ± SE with different uppercase superscripts in the same row and lowercase superscripts in the same columns are significantly different (P<0.05). C_1-Control-1 (Without hurdles), C_2-Control 2 (2% HG), T_1- (C_2 + 0.2% LA + 0.2% GDL + Non-irradiated), T_2-(C_2 + 0.2% LA + 0.2% GDL + Irradiated) and HG-Humectant, LA- Lactic acid, GDL- Glucono-Delta-Lactone (n=6)

Table.6 Effect of storage on sensory attributes of shelf stable barbecued chicken

Storage period (days)			
Samples	0	3	6
Appearance and colour			
C_1	7.00 ± 0.20^{A}	5.90 ± 0.25^{aB}	Blown
C_2	6.70 ± 0.17	6.50 ± 0.18^{b}	Blown
T_1	7.00 ± 0.25	6.55 ± 0.14^{b}	Blown
T_2	6.80 ± 0.24	6.35 ± 0.15^{ab}	Off-odour
Flavour			
C_1	6.15 ± 0.26^{b}	5.65 ± 0.30^{b}	Blown
C_2	6.55 ± 0.28^{b}	6.30 ± 0.19^{bc}	Blown
T_1	6.55 ± 0.17^{b}	6.60 ± 0.19^{c}	Blown
T_2	3.95 ± 0.32^{a}	3.90 ± 0.30^{a}	Off-odour
Juiciness			
C_1	6.30 ± 0.26	5.80 ± 0.25	
C_2	6.50 ± 0.27	6.40 ± 0.21	Blown
T_1	6.10 ± 0.36	6.40 ± 0.22	Blown
T_2	6.35 ± 0.29	6.05 ± 0.22	Off-odour
Texture			
C_1	6.50 ± 0.21	5.95 ± 0.34^{a}	Blown
C_2	6.65 ± 0.26	6.25 ± 0.15^{ab}	Blown
T_1	6.50 ± 0.22	6.70 ± 0.19^{b}	Blown
T_2	6.25 ± 0.20	5.90 ± 0.25^{a}	Off-odour
Sourness			
C_1	5.50 ± 0.15^{a}	5.75 ± 0.13^{a}	Blown
C_2	5.90 ± 0.14^{a}	6.05 ± 0.14^{ab}	Blown
T_1	6.50 ± 0.15^{b}	6.32 ± 0.17^{b}	Blown
T_2	6.55 ± 0.28^{b}	6.50 ± 0.23^{b}	Off-odour
Spiciness			
C_1	6.55 ± 0.30	5.95 ± 0.14	Blown
C_2	6.60 ± 0.31	6.15 ± 0.20	Blown
T_1	6.60 ± 0.20	6.45 ± 0.23	Blown
T_2	6.30 ± 0.23	6.05 ± 0.20	Off-odour
Overall acceptability			
C_1	6.37 ± 0.21^{bA}	5.25 ± 0.51^{aB}	Blown
C_2	6.42 ± 0.20^{b}	6.30 ± 0.18^{b}	Blown
T_1	6.95 ± 0.22^{b}	6.80 ± 0.20^{b}	Blown
T_2	5.35 ± 0.21^{a}	4.95 ± 0.24^{a}	Off-odour

Means ± SE with different uppercase superscripts in the same row and lowercase superscripts in the same columns are significantly different (P<0.05). C_1-Control-1 (Without hurdles), C_2-Control 2 (2% HG), T_1- (C_2 + 0.2% LA+0.2% GDL + Non-irradiated), T_2-(C_2 + 0.2% LA + 0.2% GDL + Irradiated) and HG-Humectant, LA- Lactic acid, GDL- Glucono-Delta-Lactone (n=6)

Flow chart for preparation of shelf stable barbecued chicken

Ready to cook chicken (1.5 to 1.8 kg)

⇩

Injection of brine solution (10% of the dressed chicken)

⇩

Brine injected chicken immersed for 12 hrs. in 2% Glycerol solution at 4^{o}C

⇩

Draining of excess solution (For 20 mins)

⇩

Injected with acidulants (Combination of 0.2% LA + 0.2% GDL weighed and diluted/mixed with 50 ml of distilled water then injected to chicken)

⇩

Draining of excess solution (For 10 mins)

⇩

Marination of chicken with curd, spice mix, condiments and lemon. Chicken kept in chiller for 3 hours (Before marination spice mix was fried in vegetable oil)

⇩

Intermittent vacuum tumbling for 45 mins (15 min tumbling + 15 min rest + 15 min tumbling)

⇩

Cooking at 150°C for 1hr (Electric oven)

⇩

Vacuum packaging (in laminated pouches)

⇩

Irradiation (at 2.5 KGy)

⇩

Stored at ambient temperature

The significantly ($p<0.05$) lower TVC and Yeast and mold counts in the hurdle treated barbecued chicken is probably due to metabolic injury to microbes as the result of lower a_w upon desorption with glycerol and lower in pH by addition of AL. These results are in agreement with Thomas *et al.,* (2007) and Karthikeyan *et al.,* (2000). The microbial profile of irradiated barbecued chicken samples in terms of TVC and Yeast and mold was significantly ($p<0.05$) lower among all samples during the storage period. This result revealed that irradiation had a significant influence on microbial count reduction. Jayathilakan *et al.,* (2009) also reported 3 log reduction in TVC and 2 log reduction in Yeast and mold counts in chicken legs upon incorporation with 2 per cent LA followed by irradiation.

Sensory evaluation

The results pertaining to changes in the sensory attributes of the barbecued chicken during ambient storage are shown in the Table 6. The appearance and colour score of C_1 sample significantly ($p<0.05$) decreased on day 3 of storage at ambient temperature. This may be due to comparatively more lipid oxidation and subsequent non-enzymatic

browning due to reaction of amino group with the oxidized compound formed (Che man *et al.,* 1995). However, all hurdle treated samples maintained this attribute upto 3 days of storage. The flavour score differed significantly ($p<0.05$) between groups. On day of processing C_1, C_2 and T_1-NIR did not show any significant difference in the flavour. However, result of sensory evaluation established that in the irradiated sample T_2-IR slight off-odour was noticed which resulted in significantly ($p<0.05$) lower flavour score among all samples and adversely affected the overall acceptability score during storage study. Off-odour in irradiated sample became more prominent on day 6 of storage. This may be due lipid oxidation induced by irradiation as reported earlier by Ahn *et al.*, (2000) and decomposition of sulfur containing amino acid *viz.* cysteine and methionine which is higher in chicken (Brewer, 2008). Nam and Ahn (2003) reported, irradiated off-odour in meat is due to formation of sulfur compounds such as dimethyltrisulfide, bismethyl-thiomethane and dimethyl sulfide. Juiciness and spiciness score did not differ significantly among groups and between storage periods. For texture score, no significant difference was noted between the groups on the day of processing. However, on day 3 of storage among the treatments, T_2-IR had significantly ($p<0.05$) lower and treatment T_1-NIR had significantly ($p<0.05$) higher score for texture. This may be due to alteration in the disulphide bond and amino acid content in the irradiated product (Santamaria *et al.,* 1992). For all samples no significant difference was noted for sourness score during storage period. Similar result was reported by Malik and Sharma (2014) in shelf stable ready to eat spiced buffalo meat product formulated with acetic acid as a AL. Between groups, the sourness score for controls was significantly ($p<0.05$) lower and for treatments score was significantly ($p<0.05$) higher during storage, which may be due to acceptable distinct sour taste developed in the treatment samples on addition of 0.2 per cent LA and 0.2 per cent GDL as blend. The overall acceptability score among treatments was significantly ($p<0.05$) higher for non-irradiated barbecued chicken (T_1-NIR) and lower for T_2-IR.

Hence, it can be inferred that non-irradiated sample is more acceptable and irradiation significantly ($p<0.05$) decreased the acceptance of the product. Whereas, Kanatt *et al.,* (2002) reported that the overall acceptability of intermediate moisture meat products is not affected by irradiation at a dose of 2.5 kGy. A shelf stable barbecued chicken having storage stability upto 3 days at ambient temperature with better sensory acceptability can be prepared by using hurdles like 2 per cent desorption solution of glycerol, 0.2 per cent LA+0.2 per cent GDL as blend and vacuum packaging.

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