

Effect of gamma irradiation and retort processing on microbial, chemical and sensory quality of ready-to-eat (RTE) chicken pulav

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Abstract

Effect of irradiation processing in combination with retort (thermal) processing on the shelf life and safety of ethnic Indian food products namely chicken pulav was investigated. Ready-to-eat chicken pulav was irradiated in air atmosphere at room temperature with ^{60}Co gamma source and retort processed at F_0 value of 3.0. Dosimetry was carried out using Ceric-Cerous dosimeter to determine the delivered dose to each sample and found to be in the range of 2.0 kGy to 5.0 kGy at a dose rate of 0.6 kGy/h with an accuracy of $\pm 5\%$. The combination processed chicken pulav was analysed for microbiological, sensory and chemical characteristics. Microbiological analysis indicated that irradiation in combination with retort processing has significantly reduced the microbial loads ($P < 0.05$). The changes in chemical characteristics and sensory quality on storage were insignificant. The combination of irradiation with retort processing resulted in greater overall reduction in microbial loads, extended shelf life and improved organoleptic qualities.

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Introduction

In both the developed and developing countries there is a growth in the demand for convenient ready-to-eat food products. There is an increasing consumer demand for high quality convenient ready-to-eat food products and has led to an increase in the commercial production of ready-to-eat products (Kamatt *et al.*, 2000; Karadag and Gunes, 2008). This special category of food has been defined as a catering system on the partial cooking of food followed by thermal processing under elevated temperature, storage in ambient condition and subsequent thorough reheating before consumption. Such foods covers a wide range of items include vegetarian and non-vegetarian foods. Retort (thermal) processing is intended to kill micro organism in food products to extend the shelf stability of the product, by the application of extreme heat condition (121.1°C). However, exposure of food to that condition may result in loss of nutritional and sensory qualities (Chiralt *et al.*, 2001). Thermal process design is adopted to maximize microbial inactivation with minimal collateral degradation to product quality (Gould, 1995). The other methods to minimize the quality degradation are combination of hurdles such as temperature (high or low), water activity, redox potential, preservatives and irradiation, which ensure stability, microbial safety

and sensory quality of food (Leistner, 2000). The use of irradiation in combination with heat was first suggested, when synergistic effects were observed for the killing of bacteria (Farkas, 1990). Irradiation applied simultaneously with, prior to, or after heating has a synergistic effect on the destruction of vegetative bacteria (Thayer *et al.*, 1995) and bacterial spores (Gombas and Gomez, 1978). Heating before irradiation enhances the antimicrobial effects of irradiation. Gamma irradiation of *Clostridium sporogenes* and *Salmonella typhimorium* with sub-lethal doses increases their sensitivity with irradiation dose. It was reported that the heat processing required to produce commercial sterility in canned luncheon meat could be reduced from F_0 - value of 4.7 to 3.4. In many countries, ionization radiation up to an overall dose of 10 kGy is accepted for commercial food processing (Lacroix and Ouattara, 2000).

Thayer *et al.* (1993) investigated the effects of heat and ionising radiation on *Salmonella typhimorium* in mechanically deboned chicken meat and reported that irradiation to a dose of 0.9 kGy caused heat sensitisation in *Salmonella typhimorium*. The radiation induced heat sensitisation was found to persist for up to 6 weeks at 5°C. This repeated synergy between irradiation and heat, coupled with the persistence of the radiation induced heat sensitisation, could be used to advantage in irradiated

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foods such as raw materials, which are cooked before consumption, cook- chill ready meals, which reheated prior to consumption.

It has been postulated that when irradiation preceded heating in the absence of atmospheric air, the enhanced killing was due to the heat as the radiation has already damaged DNA. It is also been proposed that the lethality of heating followed by irradiation was additive, reflecting two separate mechanisms of inactivation viz., while irradiation induces damages to DNA, heat induces destabilization of membranes. Overall it is observed that the combination treatment of irradiation and heat is found effective in improving the quality attributes of ready-to-eat foods while reducing the micro organisms load. The objective of this study is to determine the effect of irradiation in combination with thermal processing on microbial, chemical and sensory qualities of ready-to-eat chicken pulav, an Indian traditional non vegetarian preparation.

Materials and Methods

Food preparation

Chicken pulav (heterogeneous non vegetarian product containing raw rice, chicken, onion, garlic, ginger, spices and hydrogenated fat). The flow chart (Figure 1) illustrates the method of preparation and retort processing.

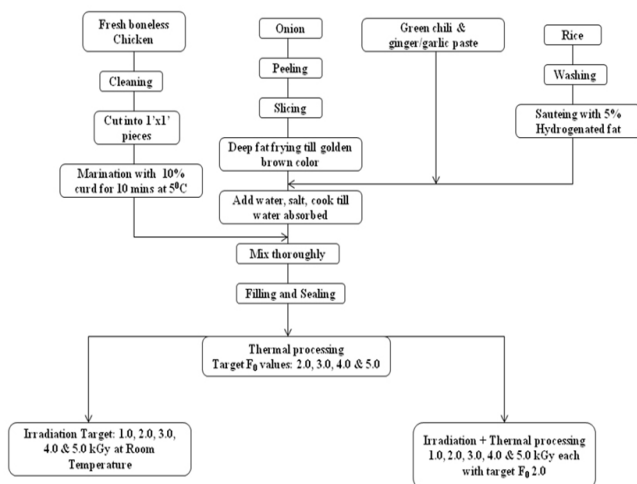


Figure 1. Flow chart of method of preparation and processing of RTE chicken pulav

Packaging material

Pre-fabricated multilayer laminated retortable pouches consisting of 12 μ m Polyester / 12 μ m Aluminium foil / 75 μ m Cast-Polypropylene (PET/Aluminium foil / C.PP) of dimension 15 cm x 20 cm were used to fill the product.

Filling and sealing

While filling exactly 275 g of the product,

the entrapped air in the head space was manually squeezed out before sealing the top of the pouch hermetically by an impulse heat sealer. The filled and sealed pouches were divided into three lots.

The following treatments were selected to produce shelf stable chicken pulav.

Treatment I: Retort pouch (thermal) processing

Target F_0 value: 2.0, 3.0, 4.0, 5.0 & 6.0

Treatment II: γ irradiation (kGy)

1.0, 2.0, 3.0, 4.0 & 5.0

Treatment III: γ irradiation + Retort pouch (thermal) processing:

1.0 kGy + F_0 3.0, 2.0 kGy + F_0 3.0, 3.0 kGy, + F_0

3.0, 4.0 kGy + F_0 3.0 & 5.0 kGy + F_0 3.0

While the first lot was subjected to γ irradiation, second lot was subjected to retort pouch (thermal) processing and third lot was subjected to combination treatment of irradiation and retort pouch (thermal) processing. During retort pouch (thermal) processing, the slowest heating zone (SHZ) in the filled pouch was determined by placing copper-constantan thermocouples at the geometrical centre of the pouches and placed at the geometrical centre of the retort. A reference thermocouple was also placed in the retort to monitor its temperature. All the thermocouples were connected to a data logger (Model: CTF 9004, M/s. Ellab, Denmark).

Gamma irradiation

Chicken pulav was subjected to γ -irradiation under ambient atmosphere using ^{60}Co γ -source in the γ -irradiator (M/s. Microtrol, Bangalore, India). Dosimetry using Ceric-Cerious dosimeter supplied by Bhaba Atomic Research Centre, Mumbai, India was carried out to determine the delivered doses. It is found that the delivered doses were in the range of 2.0 - 5.0 kGy at a dose rate of 0.6 kGy/h with an accuracy of $\pm 5.0\%$.

Retort pouch processing of chicken pulav

Retort pouch processing of chicken pulav was carried out in a steam-air retort. The retort was equipped with facility for using compressed air for over-riding pressure and a high-pressure water-circulating pump for pressurized cooling. The temperature of the product was continuously recorded during heat processing, through copper-constantan thermo couples, which were fixed at the geometric centres of the pouches. The pouches were placed at different locations in the retort. The temperature of the pouch and retort was calculated from the thermo-electro-motive-force at regular intervals of 1 min. The F_0 value was calculated from the temperature and time history. The pouches were

initially heated till their inside temperature reached 100°C. Subsequently, the pressure of the steam was raised in stages; from 5 lbs to 15 lbs. gauge pressure with the increase of temperature progressively. The processing was carried out to achieve a F_{250}^{10} value of 3.0 (Ghosh *et al.*, 1980) with maximum temperature of 118°C. After attaining the required F_0 value, the product temperature was brought down to 50-55°C by pressurized cooling (compressed air and water) in 4-5 minutes. The cooled pouches were wiped dry and examined for any visual defects.

Microbiological analysis

The combination processed chicken pulav was analysed for their commercial sterility. The pouches were incubated at 37°C and 55°C for 7 days. SPC was determined using dextrose tryptone agar (DTA) after incubation for 48 h at 30°C. Yeast and moulds were estimated with the help of acidified potato dextrose agar (PDA), after incubation at 30°C for 4-5 days. Streaking the enriched sample with selentine cystine broth at 37°C for 24 h, 48 h and 72 h were tested for salmonella and shigella. Spore formers were determined after killing the vegetative cells by keeping the sample in boiling water bath for 10 to 20 minutes and subsequently incubated at 37°C and 55°C for 48 h after incubation (Harrigan and McCance, 1976).

Storage studies

The processed chicken pulav was stored under ambient (19 – 30°C) and accelerated conditions (45°C). The samples stored at 5°C served as control. The samples were analysed at an interval of 4 months for moisture, total fat, total protein, free fatty acid (FFA) and peroxide value (PV) as per AOAC method (AOAC, 1990).

Sensory evaluation

The combination processed chicken pulav was evaluated for quality and acceptability on a 9 – point hedonic scale by semi-trained panel with score 9 for samples excellent in all respects, while 1 for highly disliked ones.

Data analysis

All the analysis was carried out in triplicate. The data were analysed statistically to find out standard deviations and significance (Snedecor and Cochran, 1988).

Results and Discussion

Processing

The product was prepared as per the recipe

$$L = \int_0^T 10^{(T-T_{ref})/z} \cdot \Delta t$$

standardized by this laboratory and retort processed as prescribed by Code of Federal Regulations. The come up time for the product to reach 100°C was 10-12 min. After attaining 100°C the product was subjected to steam-air mixture (15 lbs + 5 lbs) and the product temperature rose to 118°C in 16 min. At, 118°C the product was held for 3 min. After achieving the desired F_0 -value, the product temperature of 118°C was brought to 50-55°C by pressurized water-cooling. The time-temperature history curves of the products are shown in Figure 2.

During thermal processing, the core temperature of the products, which was measured by thermocouples, was found to increase gradually with the increase of processing time as shown in Figure 2. A reference temperature of 121.1°C was used to calculate the process lethality for *C. botulinum* using equation,

A thermal resistance (z) value of 10 obtained for the similar products was used in this calculation. At each transient time t , the process lethality rate was calculated from $10^{(T-121.1)/z}$. The total process lethality is the sum of $10^{(T-121.1)/z} \cdot \Delta t$, where time period (Δt) is 1 min.

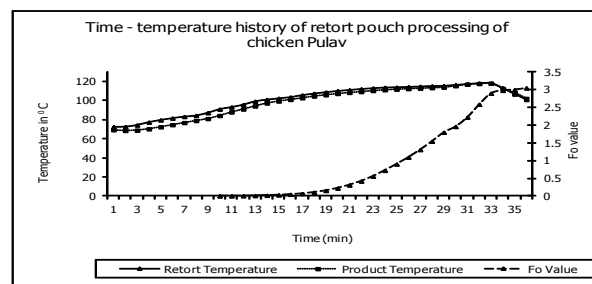


Figure 2. Time-temperature history curve of chicken pulav

Microbiological analysis

The total plate count, yeast and mould count, coliforms count and spores count were found to be Nil, Nil, -ve, $> 10^2$, $> 10^2$ and 1×10^1 , Nil, -ve, $< 10^2$, $< 10^2$ for retort processed chicken pulav having F_0 3 (Table 1) and irradiated sample (5.0 kGy) (Table 2) respectively, while the combination processed (F_0 3 + 5.0 kGy) chicken pulav (Table 3) cleared all microbiological tests and found to be sterile. The efficacy of thermo radiation requires wet conditions. The radiation resistance of *Bacillus subtilis* spores was unaffected when irradiation was carried out at 80 and 100°C. Heat and irradiation are the only two known methods of inactivating microorganisms in foods, although other processes may inhibit their development. Both heat and irradiation exert their effect by energy absorption, leading to damage to cell membranes or DNA. The energy required to

Table 1. Microbiological analysis of retort pouch (thermal) processed RTE chicken pulav

S. No.	Parameter	Control	F ₀ 2.0	F ₀ 3.0	F ₀ 4.0	F ₀ 5.0
1	Total (Aerobic) Plate Count	4 x 10 ²	2 x 10 ¹	Nil	Nil	Nil
2	Yeast and mould	>10 ¹	>10 ¹	Nil	>10 ¹	Nil
3	Total Coliforms	+ve	+ve	-ve	-ve	-ve
4	Spores					
	At 37°C	2 x 10 ⁴	2 x 10 ¹	>10 ²	>10 ¹	Nil
	At 55°C		2 x 10 ¹	>10 ²	>10 ¹	Nil

Table 2. Microbiological analysis of γ irradiated RTE chicken pulav

S. No.	Parameter	Control	1.0 kGy	2.0 kGy	3.0 kGy	4.0 kGy	5.0 kGy
1	Total (Aerobic) Plate Count	4 x 10 ²	3 x 10 ²	3 x 10 ¹	2 x 10 ²	2 x 10 ¹	1 x 10 ¹
2	Yeast and mould	>10 ¹	<10 ¹	<10 ¹	Nil	Nil	Nil
3	Total Coliforms	+ve	+ve	+ve	+ve	-ve	-ve
4	Spores						
	At 37°C	2 x 10 ⁴	>10 ⁴	4 x 10 ²	2 x 10 ²	2 x 10 ¹	<10 ²
	At 55°C		>10 ⁴	5 x 10 ²	3 x 10 ²	2 x 10 ¹	<10 ²

Table 3. Microbiological analysis of combination processed RTE chicken pulav

S. No.	Parameter	1.0 kGy +	2.0 kGy +	3.0 kGy +	4.0 kGy +	5.0 kGy +
		F ₀ 3.0	F ₀ 3.0	F ₀ 3.0	F ₀ 3.0	F ₀ 3.0
1	Total (Aerobic) Plate Count	2 x 10 ²	2 x 10 ¹	Nil	Nil	Nil
2	Yeast and mould	Nil	Nil	Nil	Nil	Nil
3	Total Coliforms	-ve	-ve	-ve	-ve	-ve
4	Spores					
	At 37°C	2 x 10 ²	2 x 10 ¹	1 x 10 ¹	>10 ²	Nil
	At 55°C	3 x 10 ²	4 x 10 ¹	1 x 10 ¹	>10 ²	Nil

Table 4. Proximate composition (wet basis)

Parameters	Result
Moisture (%)	64.15 ± 0.3174
Fat (%)	8.15 ± 0.1
Protein (%)	7.4 ± 0.05
Ash (%)	1.65 ± 0.01
Carbohydrates (%)	18.2 ± 0.25
Fibre (%)	0.45 ± 0.005
Energy	176

exert significant damage by absorption of ionizing radiation energy is much lower, however, causing only very small temperature rises in food. The decimal reduction or D₁₀ value of both vegetative microbial cells and spores decreases with increased temperature (Campbell and Grandison, 1990). Fernandez and Grecz (1969) showed the rapid acceleration in death rate of *Clostridium botulinum* 33A bacterial spores in ground beef as the temperature increased with D₁₀ value of 3.8 kGy at 0°C, 3.3 at 50°C, falling to 1.1 at 100°C. After 12 months of storage, chicken pulav didn't show any signs of microbial growth and was microbiologically safe.

Chemical analysis

The product was analyzed for its proximate composition such as moisture content, protein, total fat, total ash and carbohydrate (Table 4). The product stored under ambient and accelerated conditions was evaluated for the changes in moisture content, total fat and rancidity (Free Fatty Acids and Peroxide Value).

Figure 3 shows changes in free fatty acid (FFA) content during storage of combination processed chicken pulav had no significant (P < 0.05) effect on total acidity. It has been reported that with increasing radiation dose, the free fatty acid increased in beef

(Al – Bachir and Zeinou, 2009) and in lamb (Sweetie *et al.*, 2006). The changes in peroxide value during storage of combination processed chicken pulav are shown in Figure 4. There was no significant (P < 0.05) difference between combinations processed and control samples. Hampson *et al.* (1996) reported no significant changes in peroxide values and iodine values at low irradiation dose (< 10 kGy) in any of the meat lipids. Ouattara *et al.* (2002) reported that gamma irradiation increased lipid oxidation in ground beef samples. The lipid oxidation was attributed to the combination of free radicals with oxygen and to form hydroperoxides (Gracey *et al.*, 1999).

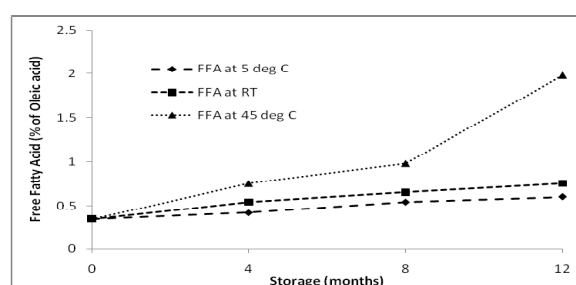


Figure 3. Changes in free fatty acid content of combination processed Chicken Pulav at 5.0 kGy + F₀ 3.0

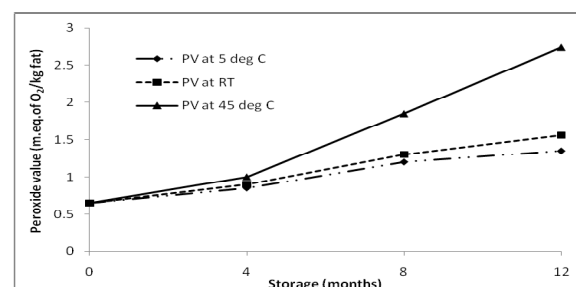


Figure 4. Changes in peroxide value of combination processed Chicken Pulav at 5.0 kGy + F₀ 3.0

Sensory analysis

The sensory analysis of chicken pulav using a 9-point hedonic (Table 5) revealed that initially the product scored 8.6 for colour, 8.5 for flavour, 8.6 for taste and 8.5 for the overall acceptability. On storage the sensory scores of the product were decreased both under ambient as well as 45°C conditions. Under ambient conditions the sensory scores decreased to 7.2 (16.27%) for colour, 7.2 (15.29%) for flavour, 7.6 (11.62%) for taste and 7.3 (14.11%) for the overall acceptance. At 45°C, the decrease was from 8.6 to 7.0 (18.60%) for colour, 8.5 to 6.9 (18.82%) for flavour, 8.6 to 7.3 (15.11%) for taste and 8.5 to 7.1 (16.47%) for overall acceptability and thus clearly indicating the effect of storage conditions on the quality attributes of the product.

The effects of selected heat, heat – irradiation combinations and irradiation treatments on the

Table 5. Sensory analysis of combination processed chicken pulav

S. No.	Parameter	Storage Condition	Storage period (Months)* (n =12)			
			0	4	8	12
1	Colour	5°C	8.6±0.32	8.3±0.44	8.0±0.55	7.6±0.56
		RT		8.1±0.52	7.8±0.49	7.2±0.62
		45°C		8.0±0.0.48	7.4±0.64	7.0±0.67
2	Flavour	5°C	8.5±0.38	8.2±0.42	7.8±0.48	7.4±0.71
		RT		8.0±0.56	7.6±0.58	7.2±0.57
		45°C		7.9±0.46	7.4±0.45	6.9±0.58
3	Taste	5°C	8.6±0.40	8.4±0.62	8.2±0.60	7.9±0.64
		RT		8.2±0.54	7.9±0.66	7.6±0.68
		45°C		8.0±0.60	7.8±0.58	7.3±0.60
4	Overall Acceptability (OAA)	5°C	8.5±0.36	8.3±0.48	7.9±0.60	7.5±0.74
		RT		8.1±0.53	7.6±0.66	7.3±0.68
		45°C		8.0±0.44	7.4±0.50	7.1±0.78

*Mean ± SD

microbiological stability and sensory qualities of shelf stable mushrooms in brine were reported by Minnaar *et al.* (1995). The use of heat – irradiation combination treatments such as target F_0 value of 2 min + 2.5 kGy at 0°C and or target F_0 value of 1 min + 4 kGy at 0°C favouring low irradiation dose levels, offered feasible alternate to thermally processed mushroom in brine from a quality point of view. In heat - irradiation combination studies of freeze sensitive, low acid starchy foods (e.g. rice), the minimum heat treatment required to render a product sufficiently cooked, should be combined with the maximum irradiation dose level that can be applied to the product (not exceeding 10 kGy) without affecting its sensory quality adversely. In a related investigation, Minnaar and McGill (1992) shown that heat – irradiation combination treatments of mushroom in brine were found to be more acceptable to a consumer sensory panel than canned products after 8 months of storage. The samples stored both under ambient and 45°C conditions were acceptable even after 12 months of storage as the OAA score of the product remained in ‘good range’. Irradiation – heat combination processing has the potential to produce high quality, shelf- stable food products.

Conclusions

Irradiation in combination with thermal (retort) processing has the potential to produce high quality, shelf stable food products. The present study shows that a low dose of irradiation followed by thermal processing at low target F_0 in achieving microbial commercial sterility and improved sensory characteristics in ready-to-eat chicken pulav.

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