Effect of retort (thermal) processing on the shelf life and safety of ethnic Indian food products namely egg curry and egg burji were investigated. Ready-to-eat egg products were packed in four layer laminated retort pouches and processed in a steam-air retort with overriding pressure. Time-temperature profile of thermal processing was determined and the same was used for heat penetration characteristics. The thermal processing parameters like retort temperature, heating lag factor \( (J_h) \), heating rate index \( (f_h) \), process time \( (B) \), \( F_0 \) value and cook value \( (C_g) \) were determined. The retort processed egg products were analysed for microbiological sensory and chemical characteristics under ambient (27–30°C) and accelerated temperature (45°C) for a period of 12 months. Microbiological analysis indicated that retort processing has significantly reduced the microbial loads \( (P < 0.05) \). The changes in chemical characteristics and sensory quality on storage were insignificant. Microbiological analysis revealed that product was commercially sterile and fit for consumption. The samples were rated excellent by the taste panel and remained in good condition even after 12 months of storage under ambient conditions.

Key words: Retort processing, egg curry, egg burji, free fatty acid, peroxide value and cook value.

INTRODUCTION

There is an increasing consumer demand for high quality convenient ready-to-eat (RTE) food products and has led to an increase in the commercial production of ready-to-eat products (Kamatt, et al., 2005, Karadag and Gunes, 2008). Retort processing has evolved significantly since its incorporation into Department of Defence (DoD) and NASA food systems. While the technology still relies on aggressive application and penetration of heat throughout foods, recent advancements in process engineering coupled with evolution of packaging technologies have allowed for an overall improvement of the technology (Lopez, 1987; Goddard, 1994; Jun et al., 2006). The current state of the art retort pouch processing has increased commercial value and can offer to consumers a level of quality, safety and convenience not realized by other means (Brody, 2002). Recent work has also...
suggested that the unique properties of retort pouches allow maximum heat penetration and reduction of nutrient losses associated with standard processing of cans (Chia et al., 1983).

Packaging has a large influence on the shelf-life of food products (Rodriguez et al., 2002). Rigid metal containers are still the most common packaging type for thermally sterilized food, but there are other packaging types with many advantages. The retort pouch is a packaging type that allows faster heat transfer than the traditional metal or glass containers, owing to their smaller profile, or more specifically, the higher surface area to volume ratio (Awuah et al., 2007; Rodriguez et al., 2002). The same microbial lethality can be achieved with a 30-50% shorter processing time, as compared to retorting of metal cans. The difference in processing time is largest for foods in which there is no natural convection in the case of metal cans (Snyder and Henderson, 2007). Most retort pouches are constructed as four-ply laminates of different packaging films that can withstand high process temperature and pressure (Jun et al., 2006). The typical retortable pouches consist of 12 μm polyester, 15 μm nylon, 9 μm aluminium foil, 80 μm cast-polypropylene. Outer polyester (polyethylene terephthalate) layer is for heat resistance and printability, an aluminium foil layer as a barrier for oxygen and light, biaxial oriented nylon for resilience, and an inner layer of cast polypropylene for pack sealing (Shihab et al., 2013; Holdsworth and Simpson, 2007). An adhesive between each layer bind the materials. Instead of using aluminium foil, some pouch materials contain silicon oxide (Holdsworth and Simpson, 2007). There is evidence that wild birds’ eggs were included in the diets of primitive people long before the development of agriculture. Today, egg remain a staple food within the human diet, consumed by people throughout the world. They are recognised by consumers as versatile and wholesome and they have a natural balance of essential nutrients. However, eggs have to compete for sales with an increasing number of other products in the modern food industry and to compete successfully they have to overcome certain disadvantages. For example, they are fragile and they deteriorate in quality with age. Furthermore, due to the natural variability in the major components of egg such as the albumen, the yolk and the shell, it poses a great challenge to meet the current demand and expectation of the consumer. Eggs consist of approximately 9.5% eggshell (including shell membrane), 63% albumen and 27.5% yolk (Cotterill and Geiger, 1977).

The main components are water (75%), proteins (12%) and lipids (12%), as well as carbohydrates and minerals (Li-Chan et al., 1995). The proteins are distributed throughout the egg, with the majority found in the egg yolk and egg white, and a small proportion in the eggshell and shell membrane (Mine, 2002). The lipids are found almost exclusively in the egg yolk, mainly in the form of lipoproteins. Several minerals have also been found in eggs, most of them in the eggshell. Carbohydrates are a minor egg component, present throughout the egg, as both free and conjugated forms, attached to proteins and lipids. The egg white or albumen makes up ~60% of the total egg weight of which water and protein are the major constituents. Egg white protein includes ovalbumin, which is the major protein followed by ovotransferrin and ovomucoid. The protein ovomucoid, is responsible for the viscosity of the albumen, lysozme, avidin, cystatin, ovoinhibitor and ovomacroglobulin (ovastatin).

Ready-to-Eat (RTE) foods are pre processed foods which are normally packed and served or consumed when required. Technological innovations, particularly in the field of food processing equipment, processing and packaging materials have brought about revolutions in the field of RTE. Indian RTE food scenario is exhibiting tremendous growth rate in the recent years and today it has become a multi billion industry with large number of firms involved. The changes in the socio-economic pattern of the society, like the changing life style, increasing number of working women, increase in the family income of people, awareness about healthy foods, changes in the meal pattern and existing food habits, desire to taste new food products have all contributed to the growth of RTE industry. Ready to eat thermally processed foods have the additional advantage that they can be stored for a period of more than one year without employing cold chain. Therefore, in this study, an attempt has been made to develop shelf-stable ready-to-eat egg curry and egg bhurji using retort pouch processing technique as well as to evaluate the changes in quality attributes under different storage.

MATERIALS AND METHODS

Egg products preparation

The ingredients used for the preparations of egg curry and egg bhurji are given in Table 1.

Egg curry

Eggs were boiled in water for 15-20 min, cooled and peeled off outer shell and cut into halves vertically. Gravy was prepared as per the standardised procedure. Gravy was filled in pouches followed by boiled egg pieces, by maintaining the ratio of drain weight.

Egg Burjii

Egg bhurji was prepared as per the standardised procedure. The prepared egg bhurji was filled and sealed in retort pouch according to the required weight.

Retort pouch processing of RTE products

Retort pouch processing of egg products were carried out in a steam-air retort, method followed by Kumar et al. (2013). 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 the inside temperature reached 100°C. Subsequently, the pressure of the steam was raised in stages; from 5 to 15 lbs gauge pressure with the increase of temperature progressively. The processing was carried out to achieve required \( F_0 \) value with maximum temperature of 121.1°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 min. The cooled pouches were wiped dry and examined for any visual defects.

### Results and Discussion

**Effect of retort processing on RTE egg products**

The egg products were prepared as per the recipe standardized by this laboratory and retort processed as prescribed by Code of Federal Regulations. During retort 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 1. A reference temperature of 121.1°C was used to calculate the process lethality for *C. Botulinum*. A thermal resistance (z) value of 10 obtained for the similar products was used in this calculation. The come up time for the egg products to reach 100°C was 10-12 min. After attaining 100°C, the product was subjected to steam-air mixture (15 + 5 lbs) and the product temperature close to 118°C in 15-16 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.

### Sensory evaluation

The egg products were evaluated at the interval of 4 months for quality and acceptability on a 9 point hedonic scale by semi-trained panelists with score 9 for samples excellent in all respects, while 1 for highly disliked ones (Ranganna, 2000).

### Data analysis

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

### Table 1. Ingredients used for the preparation of Egg curry and Egg burji

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Weight</th>
<th>Ingredient</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg (Nos.)</td>
<td>40</td>
<td>Egg (Nos.)</td>
<td>80</td>
</tr>
<tr>
<td>Onion (kg)</td>
<td>1.5</td>
<td>Onion (kg)</td>
<td>2</td>
</tr>
<tr>
<td>Tomato (kg)</td>
<td>1</td>
<td>Tomato bit (g)</td>
<td>500</td>
</tr>
<tr>
<td>Ginger paste (g)</td>
<td>100</td>
<td>Garlic paste (g)</td>
<td>50</td>
</tr>
<tr>
<td>Dhania powder (g)</td>
<td>70</td>
<td>Dhania powder (g)</td>
<td>70</td>
</tr>
<tr>
<td>Chilli powder (gm)</td>
<td>50</td>
<td>Green chilli (gm)</td>
<td>100</td>
</tr>
<tr>
<td>Garam Masala (g)</td>
<td>20</td>
<td>Turmeric powder (g)</td>
<td>5</td>
</tr>
<tr>
<td>Turmeric powder (g)</td>
<td>5</td>
<td>White pepper powder (g)</td>
<td>20</td>
</tr>
<tr>
<td>Corn flour (g)</td>
<td>30</td>
<td>Oil (ml)</td>
<td>40</td>
</tr>
<tr>
<td>Oil (ml)</td>
<td>200</td>
<td>Salt (g)</td>
<td>80</td>
</tr>
<tr>
<td>Salt (g)</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water (L)</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Proximate and chemical analysis of the sample

Proximate analysis of the samples was estimated according to AOAC (1990). Percentage of free fatty acid (FFA) expressed as oleic acid and peroxide value (PV) were estimated according to the method of Ranganna (2000).

### Microbiological analysis

The egg products were analysed for their commercial sterility. The pouches were incubated at 37 and 55°C for seven 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 four to five days. Spore formers were determined after killing the vegetative cells by keeping the sample in boiling water bath for 10 to 20 min and subsequently incubated at 37 and 55°C for 48 h after incubation (Harrigan and McCance, 1976).

### Storage

Egg products were stored under different temperatures, that is, cold storage (4-5°C), ambient temperature (27-30°C), and elevated temperature (45°C). The samples were analyzed periodically at 2 month interval for changes in peroxide value (PV) and free fatty acids (FFA).
The retort temperature was maintained at 121.1°C for both products. The \( F_0 \) values achieved was 7.77 and 7.46 for egg curry and egg burji, respectively. Our results are in accordance with other author like Frott and Lewis (1994) who studied retort processed meat products and recommended the \( F_0 \) value between 8 and 20 min for retort processed meat products. Ranganna (2000) also reported \( F_0 \) values between 8 and 12 for meat products. Gopal et al. (2001) also processed Kerala style fish curry at 121.1°C to \( F_0 \) values of 6.56 and 8.43 min. There are no literatures available regarding retort processed egg products like egg curry and egg burji in flexible laminated pouches. Whereas precooked specialty egg products such as egg patties, omelettes or cook-in-bag scrambled eggs are mainly commercialized in frozen form to fast food outlet chains in the food service industry (Baker and Bruce, 1995). However, precooked egg products, to be stored at room temperature, are not yet available in the market. In fact, only a few companies offer ready-to-eat scrambled eggs and whole hard-cooked/peeled eggs with longevity of 6 to 12 weeks at refrigerated conditions (AEB, 2003). The main challenge is to assure product safety during cooling, packaging and post packaging stages. This requires either additional thermal treatment, or an alternative treatment that has minimal effects on the product’s final quality. Thermal processing is one of the important preservation technologies for RTE food products and can be stored at ambient temperature with minimum of one year shelf life.

The retort processed egg products were analyzed for their proximate composition as given in Table 3. Moisture (%), protein (%), fat (%), carbohydrate (%) and Energy (Kcal/100g) were 84 ± 1.05, 4.5 ± 0.05, 5.5 ± 0.02, 4 ± 0.005, 84 and 64 ± 0.85, 10.7 ± 0.01, 16.5 ± 0.01, 6.8 ± 0.003, 219 for egg curry and egg burji, respectively. The FFA percentage and PV were 0.15 ± 0.03, 0.16 ± 0.03
and 0.00 ± 0.00 for egg curry and egg burji, respectively, and the same is presented in Figures 2 to 5. The RTE egg products were stored under different temperatures: (4-5°C) ambient (27-30°C) and accelerated temperature (45°C) and analyzed for its quality deterioration.

**Effect of retort processing on micro flora in egg products**

The microbiological analysis of the egg products were found to be nil and also the products remained commercially sterile during the entire period of the storage and confirmed the adequacy of the processing as well as its safety for consumption (data not shown). The proper $F_0$ value of the products rendered the commercial sterility of egg curry and egg burji.

Our result were in accordance with authors (Kumar et al., 2007; Mohammedali et al., 2013; Agathian et al., 2009) who studied retort processed ready-to-eat food; they also found commercial sterility after retort process and the entire period of the storage under different temperature. The results were in agreement with the findings of other researchers. Rajkumar et al. (2010)
determined total viable, anaerobic, coliform, staphylococcal, streptococcal, clostridial and yeast and mould counts of Chettinad goat meat curry retorted to an F₀ value of 12.1 min and showed that the product was commercially sterile.

Effect of Retort processing on physico-mechanical and barrier properties of retort pouches

Physico-mechanical and barrier properties of the retort pouches were evaluated before and after processing (Table 4). The pouch material used is similar to or better as compared to those used in similar studies. For example it has a water transmission of <0.019 g/m². This can be compared with e.g. the 0.18 g/m² for the pouches used by Rajkumar et al. (2010) and 0.21 g/m² for the pouches used by Mohan et al. (2008). According to Rajan et al. (2011) a low water vapour transmission is an indicator of suitability of the pouches for retort processing. It is also positive for the shelf-life of the product. The strength of the pouch and seal is very critical and important for avoiding bursting during processing or handling. The seal strength is also an
Our results indicate that the heat seal strength of the pouch used is 3.96 kg/10 mm if a sealing temperature of 220°C is used. This can be compared with the pouches used by Rajkumar et al. (2010) which showed a heat seal strength of 5.9-6.5 kg/15 mm. The processing effect on physico-mechanical and barrier properties of retort pouches were also evaluated and it was found that the effect of processing was insignificant. The packaging system based on aluminium foil has been reported to provide barrier against mass transfer, light and micro-organism and thus the moisture content of the product was almost retained till the completion of storage studies (Ghosh et al., 1980).

Changes in FFA and PV during storage

Figures 2 and 3 shows changes in free fatty acid (FFA) content during storage at different temperature of retort processed egg curry and egg burji had no significant (P > 0.05) effect on total acidity. The FFA content of egg curry and egg bhurji increased up to 1.32 ± 0.100%, 1.78 ± 0.105% and 1.31 ± 0.19%, 1.66 ± 0.11% under ambient temperature (27-30°C) and accelerated temperature (45°C) storage respectively. FFA correlates the possibility of breakage of long chain fatty acid chain into individual fatty acid moieties. Our results were in accordance with other authors (Aubourg et al., 1997; Aubourg et al., 1990) who studied the FFA changes in canned processed products. FFA content of the egg curry and egg burji was increased gradually, accelerated temperature (45°C) storage had a higher level when compared with other storage but the increase was within the acceptable level. Increase in FFA content was mainly due to the increased lipid hydrolysis at elevated temperature. Kumar et al. (2007), Mohammedali et al. (2013) and Agathian et al. (2009) also studied the retort processed ready-to-eat foods; and they also found a slight increase in FFA content was observed at the end of 12th month of storage period but the product was acceptable by the panelist.

The formation of peroxide during storage is slow at an induction period, the length of which will depend on the nature of fat and the presence of antioxidant. The observation also confirmed that the peroxide value of the product did not increase due to non-availability of oxygen, controlled by the packaging system (Figures 4 and 5). Peroxide values of egg curry and egg burji were increased up to 1.57 ± 0.09 meq/kg, 1.95 ± 0.17 meq/kg and 2.25 ± 0.135 meq/kg, 3.06 ± 0.135 meq/kg under ambient temperature (27-30°C) and accelerated temperature (45°C) storage, respectively. The increase in peroxide value has no significant (p > 0.05) changes as compared to samples stored under lower temperature (4-5°C). It is clearly indicating that the rancidity formation was temperature dependent. Other authors (Kumar et al., 2007; Agathian et al., 2009; Mohammedali et al., 2013) also found a slight increase in the peroxide value of retort processed samples when stored under different storage temperatures. The lipid oxidation was attributed to the

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter Specification</th>
<th>Before Retort Processing</th>
<th>After Retort Processing</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 μm Polyethylene terephthalate (PET) / 9 μm aluminium foil / 15 μm nylon / 70 μm cast polypropylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total thickness μm</td>
<td>110.00</td>
<td>110.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensile strength (machine direction) kg/cm²</td>
<td>446.58</td>
<td>437.49</td>
<td>ASTM D 882</td>
<td></td>
</tr>
<tr>
<td>Tensile strength (cross direction) kg/cm²</td>
<td>358.00</td>
<td>349.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation at break (machine direction)%</td>
<td>156.00</td>
<td>149.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation at break (cross direction)%</td>
<td>124.00</td>
<td>112.00</td>
<td></td>
<td></td>
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<tr>
<td>Tearing strength (machine direction) g</td>
<td>116.00</td>
<td>108.00</td>
<td>ASTM D1004</td>
<td></td>
</tr>
<tr>
<td>Tearing strength (cross direction) g</td>
<td>102.00</td>
<td>96.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seal strength (top) kg/10 mm</td>
<td>3.96</td>
<td>3.78</td>
<td>ASTM F88/F88M</td>
<td></td>
</tr>
<tr>
<td>Seal strength (side) kg/10 mm</td>
<td>4.86</td>
<td>4.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seal strength (bottom) kg/10 mm</td>
<td>4.02</td>
<td>3.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas transmission rate (ml/m²/day)</td>
<td>&lt;0.021</td>
<td>&lt;0.038</td>
<td>ASTM F 2622-08</td>
<td></td>
</tr>
<tr>
<td>Water vapour rate (g/m²/day)</td>
<td>&lt;0.019</td>
<td>&lt;0.032</td>
<td>ASTM F 1249</td>
<td></td>
</tr>
</tbody>
</table>

| Total migration (mg/kg) | | | |
| Distilled water | 26.0 | 28.0 | |
| 3% Acetic acid | 38.0 | 42.0 | |
| 50% Ethyl alcohol | 26.0 | 29.0 | |
| n- Heptane | 24.0 | 26.0 | |

*Before retort processing; † after retort processing.*
combination of free radicals with oxygen and to form hydroperoxides (Gracey et al., 1999). Hence, the free fatty acids of the egg products were less with the non availability of oxygen rendering less production of hydroperoxides in retort pouch processed egg products.

Effect of retort processing on sensory analysis in egg products

The sensory analysis of egg curry and egg bhurji using a 9-point hedonic (data not shown) revealed that initially the product scored 8.6 ± 0.32, 8.5 ± 0.28 for colour, 8.5 ± 0.26, 8.4 ± 0.23 for flavour, 8.4 ± 0.15, 8.5 ± 0.25 for taste, 8.4 ± 0.28, 8.4 ± 0.21 for texture and 8.4 ± 0.22, 8.4 ± 0.23 for the overall acceptability respectively. On storage, the sensory scores of the product were decreased under ambient temperature (27-30°C) and accelerated temperature (45°C) storage conditions. Under ambient conditions, the sensory scores decreased to 8.1 ± 0.22, 8.1 ± 0.24 for colour, 8.1 ± 0.30, 8.1 ± 0.30 for flavour, 8.1 ± 0.25, 8.1 ± 0.25 for taste, 8.0 ± 0.24, 8.0 ± 0.14 for texture and 8.0 ± 0.25, 8.0 ± 0.25 for the overall acceptence. At 45°C, the decrease was 8.0 ± 0.10, 8.0 ± 0.19 for colour, 8.0 ± 0.12, 8.0 ± 0.20 for flavour, 8.0 ± 0.22, 8.0 ± 0.30 for taste, 8.0 ± 0.38, 8.0 ± 0.28 for texture and 8.0 ± 0.30, 8.0 ± 0.32 for overall acceptability for egg curry and egg bhurji, respectively. These results clearly indicate the effect of storage conditions on the quality attributes of the product. Our results were in accordance with that of Gopal et al. (2001) who evaluated Kerala style fish curry and showed an overall acceptance of 8.0 on a 9-point scale rating after heat treatment, which decreased to 7.5 after 12 months of storage. Rajkumar et al. (2010) also evaluated appearance, colour, flavour, juiciness, texture and overall acceptability for Chettinad goat meat curry, showing scores of 8.0-8.4 on a 9-point hedonic scale after heat treatment.

Conclusion

Results from the temperature measurements and microbiological tests showed that the products were commercially sterile throughout the storage period. The changes in FFA and peroxide value of thermally processed egg curry and egg bhurji were insignificant, and it is possible to develop shelf stable egg products in retort pouches with good quality.

Conflict of interests

The authors did not declare any conflict of interest.

ACKNOWLEDGEMENT

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