Physicochemical and microbiological characteristics of ginger paste (cv. Suprabha) during storage in different packaging and temperature conditions

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Abstract: Shelf life quality studies of ginger paste have been carried out in three packaging materials [metalized poly-propylene (MPP), polyethylene terephthalate and high density polyethylene] at two storage temperatures [room temperature (25°C) & cold room (CT) (5°C)]. The pH, total soluble solids (TSS), total solids (TS), acidity, water activity (\(a_w\)), colour and microbial load were evaluated at 15 days interval for 120 days. There was no significant change in pH, acidity, TS and TSS of the paste with package types and storage temperatures, whereas a significant change in the total colour difference (7.406 ± 0.484 to 12.468 ± 1.288) was observed. After 120 days of storage, the minimum total bacterial count value of 4.33 ± 0.58 × 10^5 cfu/g and total mould count value of 0.9 ± 0.1 × 10^5 cfu/g were observed for samples in MPP packs stored in CT. Considering all the parameters viz. the change in colour, safety of food and nutritional quality, ginger paste can be stored in MPP pouches at 5°C temperature for 120 days.

Subjects: Food Engineering; Food Packaging; Nutraceuticals & Functional Foods

Keywords: ginger paste; storage conditions; packaging; physicochemical properties; microbial count

1. Introduction
Ginger (Zingiber officinale) is one of the earliest known oriental spices and is widely cultivated in India, particularly in the states like Kerala, Karnataka, Odisha and north eastern states. Ginger rhizomes are used both as fresh vegetable and dried spice since time immemorial and it occupies fourth
position among spices produced in India (Mohanta, Dash, Panda, & Sahoo, 2014; Thanuja, 2006). Importance of ginger is well known for its medicinal, nutritional and commercial values. One hundred grams of edible ginger contain approximately 9 g protein, 6 g fibre, 116 mg calcium, 71 g carbohydrate, and 147 IU of vitamin A (Farrell, 1999). It also contains antioxidants and is beneficial for the gastric system. Its consumption increases digestive enzyme activity and cures motion sickness, upset stomach, headache, congestion, and lowers fever when added to the bath water (Farrell, 1999).

Fresh ginger is perishable in nature and the major causes of spoilage are improper handling, growth of spoilage microorganisms, action of naturally occurring enzymes, chemical reactions and structural changes during storage. The postharvest losses of ginger are high but can be substantially minimized by processing and proper storage immediately after harvest. Though, ginger can be used to produce processed and semi-processed products such as powder, flakes, candy, ready to serve beverages, paste, etc. (Baranowski, 1985; Pezzutti & Crapiste, 1997) but, there is an urgent need to explore alternative processes for its preservation along with value added products. Ginger paste is an alternate product that can be stored for long period without much alteration of its freshness and can also be considered as a minimally processed food (Ahmed & Shivhare, 2001; Baranowski, 1985). This paste is mainly used as a spice in culinary preparations for imparting a typical fresh ginger flavour. It is a ready to use preparation that substitutes fresh ginger in homes, restaurants and institutional catering. Chemical preservatives such as sodium metabisulfite (0.5% w/w), citric acid (0.2% w/w), sodium benzoate (0.015% w/w) and sodium chloride (1.5% w/w) are generally used to increase the shelf life of ginger paste (Akhtar, Omre, & Alam, 2015). Recently, the market for spice pastes has increased significantly mainly because of the success of fast food industries and restaurants. However, the technologies of proper storage and preservation of ginger paste are often not available to the small scale processors, for which the ginger produced in small scale industries often cannot compete with the major brands available in the market. Further, the type of packaging and storage conditions often do not match the requirements of the paste, and hence, the quality of the paste deteriorates during storage. There are also degradation of colour, and other parameters limiting its shelf life and use. Study of changes in physico-chemical properties such as pH, TSS, TS, acidity, water activity, etc. as affected by the different storage conditions are important for deciding the effective shelf life of the paste and thus for recommending a suitable packaging method to the entrepreneurs. Also, change in colour and increased browning during processing and storage of processed foods are influenced by many factors like pH, acidity, storage temperature and duration etc. (Garcia, Brenes, Romero, & Garrido, 1999). Choi, Lee, Kim, and Ku (2012) investigated the effect of pre-treatment and storage conditions on the quality characteristics of ginger paste. Ahmed (2004b) reported that ginger paste at 5 (±1)°C temperature in polyethylene terephthalate or glass containers can be stored for 120 days. Unni, Chauhan, and Raju (2015) worked on high pressure processed ginger paste under refrigerated storage and concluded that the paste treated with 600 MPa pressure for 5 min could extend shelf life for 6 months under low temperature (80–85% RH) storage keeping the vital phytonutrients, organoleptic and microbiological properties for commercial applications. Akhtar et al. (2015) concluded that ginger garlic paste treated with microwave heating was more shelf stable compared to that treated with simple heating during storage for 3 months. Recently, Rubila and Ranganathan (2016) reported that ginger paste could be stored at 5°C temperature for 60 days without any microbial infestation and maintained the colour, flavour and aroma.

Literature reviews revealed that studies on physicochemical and microbiological properties of ginger paste during storage in different packaging materials and storage temperatures are limited and unsystematic (Ahmed, 2004a; Baranowski, 1985). Therefore, the main objective of the work was to produce an acceptable, shelf stable product of ginger paste by evaluating the changes in physicochemical and microbial characteristics during storage period in different environment and packaging conditions.
2. Materials and methods

2.1. Raw material and preparation of ginger paste sample

Raw ginger rhizomes of “Suprabha” cultivar were collected from farmer field after 5 months of planting which are considered to be of good quality for the ginger paste preparation as these have high dry matter and low fibre content (Sanwal, Singh, Yadav, Singh, & Misra, 2012; Sontakke & Roul, 2007). Ginger rhizomes then were washed in tap water to remove the adhering soil materials. Peeling and trimming of the rhizomes were done after soaking them in luke warm water for few minutes. Then the rhizomes were sliced to about 2 mm thickness followed by blanching at 90°C temperature for 15 min and were finally ground into puree form using a commercial wet grinder. Ginger paste was prepared by adding 15% NaCl (w/w), 0.01% citric acid (w/w), 0.002% potassium metabisulphite (w/w) and 0.1% vinegar (w/w). The flow chart for the preparation of ginger paste has been given in Figure 1.

Approximately 200 g of freshly prepared ginger paste was filled into prefabricated pouches of selected packaging materials, viz. high density polyethylene (HDPE), polyethylene terephthalate (PET) and metalized poly propylene (MPP) in replicates and sealed manually using a heat sealer after removing air bubble. The sealed packages were then stored at room temperature (RT) (20–25°C) and in cold room (CT) maintained at 5 (±1)°C for the storage and shelf life quality studies. Samples were drawn at 15 days interval up to 120 days and were analysed for quality parameters.

2.2. Physico-chemical properties analysis

2.2.1. Water activity (aw) evaluation

Water activity is a measure of the energy status of the water in a system and predicts shelf life stability with respect to microbial growth, rates of deteriorative reaction and physical properties. Water activity of the ginger paste was measured using water activity meter (Make: Labswift-aw Model: Novasina AG, Switzerland) at RT (25 ± 1°C). The results were reported as average value.

2.2.2. Total soluble solids (TSS) and total solids (TS)

The total soluble solids (TSS) (ºBrix) is the sugar content of the paste and was measured using digital refractometer (Make: Atago model: PAL3, Tokyo). Total solids were measured using gravimetric drying method taking 5–6 g of paste and drying at 80°C temperature for 42 h. The TS content of the sample was found as follows (Equation (1)) (Ranganna, 2002).

\[
TS = \text{Mass of sample} - \text{Mass of moisture evaporated}
\]
2.2.3. pH and titrable acidity

pH signifies the acidic or basic nature of the ginger paste and determines the survival and growth of microorganisms during processing, storage and distribution. pH of ginger paste was measured by a digital pH meter (EUTECH instruments, Malaysia) with glass electrode at 25°C temperature by diluting the sample at 1:2 with distil water. The titrable acidity measures the concentration of titrable hydrogen ions of the processed paste and was measured in terms of anhydrous citric acid (%) (Ranganna, 2002).

2.2.4. Colour measurement

Colour is one of the most important cues used by consumers to assess the quality of a food product. HunterLab colorimeter (Model: ColorFlex, Hunter Lab, USA) was used for measuring the surface colour in terms of lightness ($L^*$-value), redness ($a^*$-value) and yellowness ($b^*$-value) of stored ginger paste. The total colour difference ($\Delta E$) was calculated from the differences in $L^*$, $a^*$ and $b^*$ values of the paste with respect to the fresh sample and was calculated by Equation (2) (Bal, Kar, Satya, & Naik, 2011; Sahoo, Bal, Pal, & Sahoo, 2014).

$$\Delta E = \sqrt{\Delta L^*^2 + \Delta a^*^2 + \Delta b^*^2}$$  

(2)

2.3. Microbiological analysis

Microbiological analysis signifies the shelf life stability of the product. Ginger paste samples were examined for microbiological analysis immediately after processing and on days of sample analysis throughout the storage period according to the standard methods for the populations of mesophilic aerobic bacteria and total mould load (Collins, 1967; Julseth & Deible, 1974).

2.3.1 Total bacterial count (TBC)

Twenty-eight grams of Nutrient Agar (NA) of Himedia make (M001–500G) was suspended in 1 L distilled water by boiling followed by sterilizing at 15 lbs for 15 min and pH was adjusted to 7.4 at 25°C temperature. Pour plate technique after serial dilutions in sterile distilled water (0.1% w/v) was used in all tests. The first dilution was prepared by blending 25 g of sample with 225 ml of sterile distilled water and further dilutions were made according to the need. Duplicate plates were used for each dilution. Total viable bacteria count of samples was determined on plate count agar after incubation at 37 (±2)°C temperature for 48 h according to the standard method (Collins, 1967; Julseth & Deible, 1974).

Figure 2. (A) Changes of water activity and (B) TSS during storage.
Table 1. a_TSS, TS, pH, acidity, ΔE, TBC and TMC values of ginger paste on 120th day of storage

| Type of package | Storage temperature | Water activity | TSS (ºB) | TS (%) | pH | Acidity (%) | ΔE | TBC × 10⁵ cfu/g | TMC × 10⁵ cfu/g |
|-----------------|---------------------|----------------|----------|---------|----|-------------|----|----------------|----------------|
| HDPE            | CT                  | 0.737 ± 0.009ᵃ  | 24.033 ± 1.747ᵃ | 28.221 ± 1.217ᵃ | 3.217 ± 0.006 | 1.301 ± 0.133ᵃ | 08.698 ± 0.670 | 5.333 ± 0.578ᵃ | 0.967 ± 0.058ᵃ |
|                 | RT                  | 0.740 ± 0.009ᵃᵇ | 24.800 ± 0.520ᵃᵇ | 29.912 ± 0.593ᵃᵇ | 3.187 ± 0.015ᵃᵇ | 1.344 ± 0.111ᵃᵇ | 12.468 ± 1.288ᵃᵇ | 7.000 ± 1.000 | 1.333 ± 0.153ᵇ |
| MPP             | CT                  | 0.736 ± 0.008ᵃ  | 25.167 ± 0.850ᵃ | 28.508 ± 0.651ᵃ | 3.193 ± 0.011ᵃ | 1.109 ± 0.037ᵇ | 07.406 ± 0.484ᵃ | 4.333 ± 0.578ᵇ | 0.900 ± 0.100ᵃ |
|                 | RT                  | 0.744 ± 0.008ᵇ  | 25.433 ± 1.201ᵇ | 30.565 ± 0.832ᵇ | 3.190 ± 0.026ᵇ | 1.131 ± 0.037ᵇ | 11.616 ± 0.709 | 5.333 ± 0.578ᵇ | 1.200 ± 0.100 |
| PET             | CT                  | 0.734 ± 0.009ᵃ  | 23.533 ± 0.808ᵃ | 29.640 ± 0.517ᵃ | 3.190 ± 0.026ᵃ | 1.408 ± 0.000 | 07.984 ± 0.924ᵃ | 4.667 ± 0.578ᵇ | 0.933 ± 0.058ᵇ |
|                 | RT                  | 0.741 ± 0.008ᵇ  | 23.833 ± 0.635ᵇ | 30.590 ± 0.356ᵇ | 3.187 ± 0.015ᵇ | 1.344 ± 0.064ᵃ | 12.302 ± 1.243ᵇ | 5.667 ± 0.578ᵇ | 1.300 ± 0.100ᵇ |

Notes: CT-cold temperature, RT-room temperature.
The mean values with same superscripts are statistically not significantly different.
2.3.2. Total mould count (TMC)

Thirty-nine grams of Potato Dextrose Agar (PDA) of Himedia make (M096–500G) were suspended in 1 L distilled water by boiling followed by sterilizing at 15 lbs for 15 min and pH was adjusted to 5.6 at 25°C temperature. The plates were incubated at 37 (±2)°C temperature for 3–4 days. All tests were carried out in replications and the mean values were reported. Results were expressed as colony forming units per gram (cfu/g) (Collins, 1967; Julseth & Deible, 1974).

2.4. Analysis of data

The experiments were planned using factorial completely randomized design (CRD) with three replications using SAS version 9.3. The data obtained were submitted to analysis of variance and the least significant differences were used to compare the different treatments individually.

3. Results and discussion

3.1. Physicochemical properties during storage

3.1.1. Water activity

The water activity almost remained constant during the first 6 weeks of storage after that it started reducing slightly (Figure 2(A)). The water activity of the samples was found to be between 0.744 (±0.008) and 0.734 (±0.009) at the end of 120 days of storage (Table 1). The lower water activity in general indicates higher stability of the commodity against microbial destructions. The 15% (w/w) salt concentration in the prepared ginger paste and lower water activity (<0.9) might have hindered the growth of halophilic bacteria and osmophilic bacteria. High salinity represents an extreme environment that relatively few organisms can adapt and occupy. Most halophilic and all halotolerant organisms expend energy to exclude salt from their cytoplasm and to avoid protein aggregation (salting out). In order to survive in the high salinities, halophiles employ strategies to prevent desiccation through osmotic movement of water out of their cytoplasm. As the storage period was increased, number of microorganisms also increased. The free water present in the ginger paste might have been taken up by the bacteria from the surrounding through their cell wall resulting in reduction in water activity in the surroundings.

3.1.2. TSS and TS

There was no systematic change in the TSS values of the ginger paste, though in general there was a slight increase in the TSS value during storage (Figure 2(B)). The TSS of ginger paste changed from the initial value of 22.65 (±1.03) ºBrix to a minimum of 21.63 (±0.76) ºBrix and a maximum of 25.433 (±1.2) ºBrix in different packaging conditions after 120 days of storage (Table 1). Topno et al. (2013) reported similar results for ginger-garlic paste in retort pouches. TS almost remained constant during the storage period, which ranged from 28.22 (±1.22) to 30.59 (±0.36)% for all the packaging material after 120 days of storage (Figure 3(A)). It indicated that all the selected packaging materials effectively prevent moisture loss from the samples (Rao & Steffe, 1992; Sanwal et al., 2012).

3.1.3. pH and titrable acidity

The pH of the paste did not vary significantly during the storage which changed from the initial value of 3.11 (±0.01) to between 3.19 (±0.02) and 3.22 (±0.01) in different packaging conditions (Figure 3(B)). Similar observations were also reported for ginger paste stored in HDPE, PET and glass jars (Ahmed & Shivhare, 2001; Sontakke & Roul, 2007). Lower the pH resulted in more stability against microbial spoilage of the commodity. As such the ginger paste was found to be stable against bacterial spoilage up to 120 days of storage. Previously similar results have been reported for minced ginger during refrigerated storage (Choi, Kim, Lee, & Lee, 2002) and ginger paste undergoing pre-treatment and storage conditions (Choi et al., 2012).
The initial value of the acidity was observed to be 1.13 (±0.06)% which changed to a minimum of 0.98 (±0.13)% and maximum of 1.56 (±0.2)% during the storage period (Figure 4(A)). It was observed that there was no significant variation in the acidity of the paste during storage. Similar observations were made for garlic puree/paste (Ahmed & Shivhare, 2001) and for ginger paste (Ahmed, 2004b).

3.1.4. Colour changes
Figure 4(B) shows the change in colour of all the ginger paste samples kept in different conditions. The maximum change in colour (Δ\(E\)) took place during the first 6 weeks of storage and subsequently rate of change reduced. It was observed that in general, Δ\(E\) was higher for the RT stored samples.
than the cold stored samples. Higher ΔE in RT might be due to the effect of higher temperature than CT. Discolouration and non-enzymatic browning due to thermal treatments could result from several reactions, including Maillard condensation, caramelization and destruction of pigments (Ibarz, Pagan, & Garza, 2000). The samples stored in MPP pouches in CT condition were found to be the best in terms of colour retention. The results were in agreement with Unni et al. (2015) for high pressure processed ginger paste under refrigerated storage. Rubila and Ranganathan (2016) also reported the same result of colour change for accelerated shelf life study of ginger paste.

3.1.5. Microbial stability of ginger paste
Both TMC and TBC increased with the storage period. The TBC of the paste changed from the initial value of 1.33 (±0.25) × 10⁵ to 7 (±1.0) × 10⁵ cfu/g in different packaging conditions (Figure 5(A)). The acceptable limit of the total plate count is 5 × 10⁵ cfu/g for herbs and spices and for the foods that needs further cooking before consumption (Topno et al., 2013). It was observed that all the ginger paste samples in CT were within acceptable limit except those in HDPE packages on 120th day of storage. The samples in different packaging materials at RT were not acceptable at the end of 120 days of storage (Table 1).

The total mould count of the paste changed from the initial value of 0.33 (±0.03) × 10⁵ to 1.33 (±0.15) × 10⁵ cfu/g in different packaging conditions (Figure 5(B)). Considering 1 × 10⁵ cfu/g as the acceptable limit of moulds (Anonymous, 1995), the sample stored in HDPE and PET at RT were not acceptable after 105th days of storage.

Mould can favourably grow in the paste which might be due to the water activity (>0.7) of the samples. Low moisture, low temperature and high salt are unfavorable for the growth of bacteria, but it provides a conducive environment for the growth of yeast and moulds. However, yeasts and moulds are also acid tolerant and can grow at pH < 0.4 (Plotto, 2002).

For 90 days of storage period all the samples in different packaging materials and storage temperatures were acceptable from the bacterial count point of view. However, as regards to mould count, only the samples stored at 5°C temperature were acceptable. The samples stored in different packages at 25°C were beyond the acceptable limit of mould count (1 × 10⁵ cfu/g). For 120 days of storage, only the samples stored in MPP and PET at 5°C storage temperature were acceptable in view of safe bacterial load, but the mould count within all the packaging materials kept at 5°C were within the acceptable limit.
4. Conclusions

The physico-chemical properties of ginger paste of Suprabha cultivar, except the colour, did not change significantly with the variation in storage temperature and type of packaging materials. The colour degraded more for the samples stored at RT than the CT stored samples. A significant difference in microbial load was observed with different packaging materials and storage temperatures. The TBC and TMC increased with the storage period. Considering the change in colour and safety of food, ginger paste in MPP pouches at 5°C may be recommended to store up to 120 days. Further, more studies using various advanced techniques of non-thermal processes are needed to extend the shelf life of the ginger paste.

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Competing Interests

The authors declare no competing interest.

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