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Estimation of Shelf Life and Development of Packaging Standards for Bulk Packaging of Orthodox Tea [*Camellia sinensis* (L.) Kuntze] for Export

Donal Bhattacharjee[1], Pooja Patriwar[1], Vaishali Ravandale[1], S.H. Bandekar[1], Bidhan Das[2], Babu Rao Guduri[1], Tanweer Alam[3]

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ABSTRACT

Background: Tea is a shelf-stable product in which respiration processes are suspended, but biochemical, microbial and other decomposition processes continues depending upon the storage conditions. Considering the present problems, a study was undertaken with the objective to develop bulk packaging of Orthodox tea by taking up testing of packaging materials, shelf life studies and laying out specifications for bulk packaging of tea for the export market.

Methods: The tea samples were packed in ten different packaging materials and exposed to accelerated climatic conditions (38±1°C and 90±2% RH) for a period of four months. The experiment was laid out in completely randomized design and replicated thrice.

Result: The moisture content of Orthodox tea was showed a gradual increase during the exposure period. Heavy metals, total ash content and tannin content were found in permissible limits. The sorption isotherm of Orthodox tea was characterized by a sigmoid shape curve. No damage to the packaging materials was observed during transport worthiness test. The maximum shelf life of 105 days was attained in sandwich bag and PP woven sack with LDPE-EVOH-LDPE liner and 4 ply Multiwall Paper Sack with two liners at accelerated conditions. Based on this, it was concluded that the maximum estimated storage life at 27±1°C and 65±2% RH was 315 days and the same can be achieved by sandwich bag and PP woven sack with LDPE-EVOH-LDPE liner and 4 ply Multiwall Paper Sack with 7 μ Aluminium Foil/poly liner and 12 μ MET PET/poly liner.

Key words: Orthodox tea, Packaging, Quality, Shelf life, Storage.

INTRODUCTION

Tea is the most popular and commonly consumed non-alcoholic aromatic beverage in the world. Tea is processed from two to three tender leaves and an unopened apical bud of *Camellia sinensis* (L.) Kuntze, the flowering plants in the *Theaceae* family and has two main varieties: *Camellia sinensis* var. *sinensis* and *Camellia sinensis* var. *assamica* (Zhang *et al*., 2019). India is the second largest producer of tea next to China and over 70% of the production is used for domestic consumption. India is home for well-known premium teas such as Darjeeling and Assam Orthodox. Both of these teas are protected under Geographical Indication which defines its authenticity and quality (Baruah, 2017). The fresh tea leaves contain polyphenols, amino acids, vitamins, proteins, carbohydrates, trace elements like Mg, Cr, Fe, Cu, Zn, Na, Co K *etc*. Polyphenols and Catechins have antioxidant properties which protects cell membranes from oxidative damage (Malabadi *et al*., 2022; Khan and Mukhtar, 2007). Studies have shown that these phyto-components reduce risk of cancer, cardiac diseases, diabetes, cholesterol, weight loss and it also has antimicrobial, anti-inflammatory, anti-allergic, anti-viral and anti-carcinogenic properties (Deka and Vita, 2011; Sen and Bera, 2013).

Tea is mainly classified on the basis of processing and categorized as black tea (fully fermented or oxidized tea), green tea (non-fermented or unoxidized) and oolong tea (semi/ partly fermented) (Sacthivel *et al*., 2020; Gardner *et al*., 2007; Schillinger *et al*., 2010). The stages in the processing of tea include plucking (harvesting/picking), withering, macerating, rolling, fermenting (oxidizing) and drying. There are two chief methods for manufacturing tea *viz.* crush, tear and curl (CTC) and Orthodox. The Orthodox tea is the whole leaf tea which involves a roller or manual hand rolling whereas CTC tea is chopped into small and uniform pieces, generating granular leaf particles produced using a suitable maceration device. Orthodox tea is premium, more expensive to make and the brew emanates a rich

[1]Indian Institute of Packaging, Mumbai-400 093, Maharashtra, India.
[2]Indian Institute of Packaging, Kolkata-700 091, West Bengal, India.
[3]Indian Institute of Packaging, Delhi-110 001, India.

Corresponding Author: Tanweer Alam, Indian Institute of Packaging, Delhi-110 001, India. Email: amtanweer@rediffmail.com

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aroma and colour (Roy, 2013; Mahejabeen and Syed, 2011; Pou, 2016). So, the manufacturing process essentially involves disruption of the cellular integrity of tea shoots, thereby enabling the mixing up of substrates i.e. polyphenols and the enzymes (polyphenol oxidases). This results in the initiation of a series of biochemical and chemical reactions with the uptake of atmospheric oxygen and formation of oxidized polyphenolic compounds that are characteristic of tea along with volatile flavour compounds that impart characteristic aroma to tea. It is followed by drying to arrest the enzymatic reactions. Finally, the leaves are graded according to their sizes as whole leaf, brokens, fannings and dust by sieves (Baruah and Mahanta, 2003).

India is endowed with the ideal agro-climatic conditions for tea cultivation and has evolved to be one of the most technologically equipped tea industries in the world but unfortunately the tea manufacturers pay inadequate attention to tea packaging. Due to this the tea industry face great challenges in terms of maintenance of quality in the export market. Tea is a hygroscopic product so it requires higher barrier properties of the tea packaging materials. Presently, tea is exported in bulk packages without any technical specifications regarding packaging due to which the exporters are unable neither to maintain the consistent quality of tea nor assess the shelf life. Tea is a shelf-stable product in which respiration processes are suspended, but biochemical, microbial and other decomposition processes continues depending upon the storage conditions. Considering the present problems, a study was undertaken by Indian Institute of Packaging (IIP), Mumbai in collaboration with Tea Board India under Ministry of Commerce and Industry, Government of India with the objective to develop bulk packaging of Orthodox tea by taking up testing of packaging materials, shelf life studies and laying out specifications for bulk packaging of tea for the export market.

MATERIALS AND METHODS

Orthodox tea was procured from M/s Andrew Yule and Company Limited, a Government of India Enterprise and packaging of samples was carried out at the Rajgarh Tea Estate at Dibrugarh district in Assam. The present investigation was carried out based on the survey conducted by Indian Institute of Packaging, Mumbai in FY 2021-22. For packaging of the Orthodox tea, Sandwich bag and Polypropylene (PP) woven sacks were selected with three liners. The Liner I was made up of mono layered film of high molecular high density Polyethylene (HMHDPE). The Liner II was 3 layered film of low density Polyethylene- high density Polyethylene- low density Polyethylene (LDPE-HDPE-LDPE). The Liner III was 5 layered film of low density Polyethylene-Ethylene vinyl alcohol-low density Polyethylene (LDPE-EVOH-LDPE). The multiwall paper sack of 4 ply and 2 ply with Aluminium foil and metallised polyethylene terephthalate (MET PET) were selected as alternative packaging materials. These packaging materials were tested for physical, mechanical and physico-chemical properties in order to evaluate their quality (Table 1, 2 and 3). The storage studies of Orthodox tea were conducted in all the packaging materials by the method of accelerated shelf life testing to measure the shelf-life in a shorter period of time using harsher conditions. The samples were exposed to accelerated condition of 38±1°C and 90±2% R.H. (Newtronic Walk-In Humidity Chamber) for a period of four months. The moisture present in Orthodox tea samples was analyzed using the AOAC (2000) method by drying the sample in a hot air oven at 105±2°C till the weight of the sample became constant. The final result was expressed as per cent moisture content. The heavy metals present in the exposed Orthodox tea were analyzed by weighing 2-3 g of sample and it was placed in the holder of an energy-dispersive X-ray fluorescence spectrophotometer (Shimadzu EDX- 720) and the values were recorded. The ash content in Orthodox tea was determined by heating the tea in a silica crucible on oxidizing flame and then ignited in a muffle furnace at 550±10°C for six hours. The process was repeated until the difference between two successive weighing was less than 1 mg and ash content was calculated as follows (FSSAI, 2015).

$$\text{Total ash (\% on dry weight)} = \frac{(W_2 - W) \times 100 \times 100}{(W_1 - W) \times (100\text{-}M)}$$

Where,

W_2 = Weight in g of Silica dish + water insoluble ash.
W = Weight in g of empty dish.
W_1 = Weight in g of dish with material.
M = Percentage of moisture.

The total tannin present in Orthodox tea was estimated by the titrimetric method. For qualitative analysis, a decoction of 1 g tea was prepared in 25 ml distilled water with the help of a heating magnetic stirrer for 5 minutes at 70°C. It was cooled, filtered through Whatman No.1 filter paper and centrifuged at 10000 rpm for 15 minutes. The supernatant was collected and stored at 4°C. The presence of tannins in the tea was determined by adding 2-3 drops of 5% (w/v)

Table 1: Specification of sandwich bag and pp woven sack.

Test	Sandwich bag	PP woven sack
Material of construction of sack	Non-woven fabric laminated to	Polypropylene
Dimensions (mm)	1000 × 643	970 × 610
Tare weight (g)	125.79	99.33
No. of runs of stitches	-	2
Grammage (g/m²)	146.42	90.61
Thickness (µ)	265	120
Mesh	38 × 39	40 × 39
Denier (g/900 m)	729	711
Seam strength (Kgf)	32.73	44.17
Breaking strength (Kgf)	D1 = 63.79	D1 = 49.71
	D2 = 47.85	D2 = 37.80

(D1= Warp, D2- Weft).

aqueous solution of ferric chloride to 1 ml of extract. The formation of greenish precipitate specifies the presence of tannins in the sample (Khasnabis *et al*., 2015). For quantitative analysis of tannins, 25 mL of infusion, 25 mL of indigo carmine solution and 750 mL of distilled deionised water was measured into 1 L conical flask and titrated against 0.1 N aqueous solution of $KMnO_4$ until the blue coloured solution changes to green and finally to golden yellow. A blank was run without sample and total tannin content was estimated as follows (Atanassova and Bagdassarian, 2009).

$$T (\%) = \frac{(V - V_0) \times 0.004157 \times 250 \times 100}{g \times V_1}$$

Where,

V = Volume of 0.1 N aqueous solution of $KMnO_4$ for the titration of the sample (ml).

V_0 = Volume of 0.1 N aqueous solution of $KMnO_4$ for the titration of the blank sample (ml).

0.004157 = Tannins equivalent in 1 ml of 0.1 N aqueous solution of $KMnO_4$ (g).

250 = Volume of the volumetric flask (ml).

g = Gram of the sample taken for the analysis (g).

V_1 = Volume of Indigo carmine solution (ml).

100 = Per cent (%).

The sorption isotherm of the product indicates the relationship between water content and water activity at a constant temperature. The sorption isotherm of Orthodox tea was determined by the static method. A range of relative humidity conditions were built up in the desiccators by means of the salt solutions. In each desiccator, one relative humidity condition was created ranging from 7% to 84%. Pre-weighed samples of the tea were exposed to each of these relative humidity conditions (Dmowski and Ruszkowska, 2018). The constant temperature of 27±2°C was maintained throughout the experiment. This was continued till the product achieved equilibrium with the condition to which it was exposed. A graph of sorption isotherm was plotted (Fig 1). The transport worthiness test was conducted to evaluate the transportation hazards and performance of the bulk packages during the transit. It was performed by drop test and vibration test of the packaged Orthodox tea sample. For drop test, total three sequential drops on each sack from a drop height of 1.2 m were carried out. The first drop was flat on one of the faces,

Table 2: Specification of liners.

Test	Liner I	Liner II	Liner III
Material of construction	HDPE	LDPE	EVOH
Dimensions (mm)	1025 × 665	990 × 645	1025 × 665
Seal strength (gf)	2509.22	4610.08	1405.77
Thickness (µ)	42	75	40
Tensile strength (Kg/cm²)	D1 = 254.76	D1 = 222.13	D1 = 177.50
	D2 = 248.35	D2 = 185.79	D2 = 166.36
Elongation (%)	D1 = 10.22	D1 = 394.83	D1 = 18.28
	D2 = 501.83	D2 = 457.51	D2 = 509.57
WVTR (g/m²/24 hrs)	6.22	3.84	3.51

(D1- Lengthwise, D2- Crosswise, WVTR- Water vapour transmission rate).

Table 3: Specification of 4 ply multiwall paper sack with aluminium foil/poly liner and MET PET/poly liner.

Test	4 Ply multi wallpaper sack with zluminium foil/poly liner	4 Ply multi wallpaper sack with MET PET/poly liner
Material of construction of sack	Sack Kraft	Sack Kraft
No. of Plies	4	4
Length of sack excluding bottom gusset (mm)	658.00	658.00
Width of sack (mm)	611.00	611.00
Bottom gusset width (mm)	190.00	190.00
Grammage of individual ply (g/m²)	81/82/85/114	80/80/80/113
Tare weight (g)	395.00	395.00
Tensile Index of individual ply (Nm/g)	MD = 57/38/32/33	MD = 59/42/36/57
	CD = 56/22/21/29	CD = 58/25/24/33
Elongation of individual ply (%)	MD = 7.91/2.72/2.41/3.10	MD = 7.17/3.13/2.38/3.40
	CD = 7.01/2.31/2.42/3.02	CD = 8.06/1.16/1.16/2.09
Burst index of individual ply (Kpam²/g)	8/3/3/3	8/3/2/5
Tear index of individual ply (mNm²/g)	MD = 16/6/4/10	MD = 9/2/3/4
	CD = 19/6/5/12	CD = 9/4/3/2
Air permeability of individual ply (ml/minute)	1300/190/185/85	1350/160/170/80

(MD- Machine direction, CD- Cross direction).

second drop was flat on one of the edges and third drop was flat on the bottom (IS 7028-4 1987). For vibration test, the packed Orthodox tea was kept on the vibration table and vibrated for one hour at a frequency of 120 cpm and 2.54 cm amplitude (IS 7028-2 2002).The experiment was laid out in completely randomized design with three replications, by adopting the standard statistical procedures of Gomez and Gomez (1984). The data obtained were subjected to analysis of variance (ANOVA) with significance level $p<0.05$. The means between treatments were compared by Duncan's multiple range tests (DMRT) (Duncan, 1955).

RESULTS AND DISCUSSION

Moisture content

The results obtained from analysis of moisture content of Orthodox tea showed a gradual increase in the moisture uptake in all the packaging materials (Table 4). The initial moisture content was 2.93% and highest moisture content reported was 7.45% (PP woven sacks with Liner II: LDPE-HDPE-LDPE) after 120 days of storage. According to FSSAI's (Food Safety and Standards Authority of India) Food Safety and Standards (2011), the critical moisture content of black tea considered was 7.00% and as the exposed tea samples exceeded this limit and in some of the packaging materials fungus growth was observed (Fig 2), they were discarded and sampling was discontinued further. Based on the moisture content the maximum shelf life of 105 days was achieved by Orthodox tea in PP woven sack and sandwich bag with Liner III: LDPE-EVOH-LDPE and 4 ply Multiwall Paper Sack with 7µ Aluminium Foil/poly liner and 4 ply Multiwall Paper Sack with 12µ MET PET/poly liner at accelerated conditions. The chief causes for quality deterioration of tea during storage were moisture content and permeability of packaging materials. The steady moisture content in the samples could be attributed to the barrier feature of PP woven sack and sandwich bag with Liner III: LDPE-EVOH-LDPE and 4 ply Multiwall Paper Sack with 7µ Aluminium Foil/poly liner and 4 ply Multiwall Paper Sack with 12µ MET PET/poly liner. EVOH coextruded with LDPE has one of the lowest oxygen permeability and excellent barrier properties against other gases, such as nitrogen and carbon dioxide. In addition, it also prevents the scalping of aromas and flavours in food packaging (Mokwena and Tang, 2012; Armstrong *et al*., 2010; Maes *et al*., 2019). Aluminium Foil and MET PET also has superior oxygen barrier and good moisture barrier (Mokwena and Tang, 2012). Tea is hygroscopic in nature and this affinity for water is caused by the hydroxyl groups available in the cell walls of tea. The packed tea may undergo undesirable changes in its quality during storage and transportation due to fluctuations in relative humidity and temperature which can affect the tea's hygroscopicity (Dmowski and Ruszkowska, 2018). So, the mechanical and barrier properties of the packaging materials have to be considered while packaging the tea. Similar results were reported by Debnath *et al*. (2012) and Dmowski and Ruszkowska (2018).

Heavy metal content

The heavy metals like lead and copper content were also considered as the deteriorating factor during the storage of

Table 4: Moisture content in Orthodox Tea during exposure period.

Packaging materials	Moisture content (%)								
	Days in storage								
	0	15	30	45	60	75	90	105	120
T_1	2.93	3.48e	4.23f	4.71c	5.58d	6.39*c	7.47e	-	-
T_2	2.93	3.37cd	4.06d	4.85d	5.69d	6.74*d	7.25d	-	-
T_3	2.93	3.21b	3.91c	4.56b	5.06b	5.85b	6.28b	6.69*b	7.27a
T_4	2.93	3.87g	4.63g	5.52g	6.92*f	-	-	-	-
T_5	2.93	3.61f	4.73g	5.69h	6.81*f	7.45e	-	-	-
T_6	2.93	3.45de	4.18ef	4.85d	5.16bc	5.76b	6.04a	6.79*b	7.37a
T_7	2.93	3.05a	3.49a	3.83a	4.24a	5.18a	5.96a	6.33*a	7.21a
T_8	2.93	3.17b	3.74b	4.62bc	5.12bc	5.76b	6.28b	6.73*b	7.31a
T_9	2.93	3.34c	4.09de	4.97e	5.23c	5.84b	6.67*c	7.22c	-
T_{10}	2.93	3.46de	4.02cd	5.14f	5.98e	6.74*d	7.39 de	-	-
C.D. (0.05)	-	0.092	0.114	0.111	0.119	0.118	0.124	0.107	N.S
SEm±	-	0.031	0.038	0.038	0.040	0.039	0.041	0.033	0.049

*Sampling was discontinued further as the sample exceeded critical moisture content (CMC-7.00%) at this stage.

(Means in the column followed by the same alphabet do not differ significantly by DMRT at 5%) N.S-Non significant.

(T_1- Sandwich bag with Liner I: HMHDPE, T_2- Sandwich bag with Liner II: LDPE-HDPE-LDPE 3 layered film, T_3- Sandwich bag with Liner III: LDPE-EVOH-LDPE 5 layered film, T_4- PP woven sacks with Liner I: HMHDPE, T_5- PP woven sacks with Liner II: LDPE-HDPE-LDPE, T_6- PP woven sacks with LDPE-EVOH-LDPE, T_7- 4 ply Multiwall Paper Sack with 7 µ Aluminium Foil / poly Liner, T_8- 4 ply Multiwall Paper Sack with 12 µ MET PET/ poly Liner, T_9- 2 ply Multiwall Paper Sack with 7 µ Aluminium Foil / poly Liner, T_{10}- 2 ply Multiwall Paper Sack with 12 µ MET PET/ poly Liner).

tea in packaged condition. As per Bureau of Indian standard's norms, the maximum permissible limit of lead is 10 ppm and copper is 150 ppm (IS 3633:2003). Based on the test results, it was observed that even after exposure of the packaged samples in the accelerated condition, the tea sample showed no heavy metals. The adverse health effects of various heavy metals on human include endocrine disruption, cytotoxicity, mitochondrial dysfunction and oxidative stress (Chen *et al*., 2010; Belyaeva *et al*., 2012).

Ash content

The ash contents for the Orthodox tea packed in different packaging materials ranged from 5.61-6.97 % (Table 5). The amount of total ash showed variations during the entire period of storage but the values were within the permissible limits as prescribed by FSSAI (Food Safety and Standards, 2011). The mineral and moisture content in tea correlates with ash content. The mineral content part measures physiological ash, which is derived from the plant tissues and non-physiological ash, is the residue of the extraneous matter like sand and soil adhering to the plant surface. The higher ash content in tea might be due to less moisture content in tea. The composition of the ash of tea also varies with the age of the leaf because the water-soluble potash and phosphoric acid diminishes as the leaves

Table 5: Total ash content in Orthodox tea during exposure period.

Packaging materials	Total ash content (%)								
	Days in storage								
	0	15	30	45	60	75	90	105	120
T_1	5.61	4.88b	5.32a	6.75h	5.93e	5.61b	5.29*c	-	-
T_2	5.61	5.74d	5.69c	5.81efg	4.90b	5.72bc	5.89*e	-	-
T_3	5.61	5.44c	6.75f	5.78def	5.91e	5.87d	4.65a	5.92b	6.18*c
T_4	5.61	4.67a	5.84de	5.92g	5.74*d	-	-	-	-
T_5	5.61	5.97e	5.51b	5.73de	4.89b	6.63*e	-	-	-
T_6	5.61	6.97f	5.74cd	5.86fg	5.62d	5.84d	4.82b	6.53c	5.77*b
T_7	5.61	5.44c	5.79cd	5.18b	4.67a	5.48a	5.61d	5.92b	6.75*d
T_8	5.61	5.74d	5.93e	5.69d	4.98b	5.88d	6.04e	5.77a	5.48*a
T_9	5.61	5.74d	5.92e	5.49c	4.97b	5.78cd	5.33c	6.81*d	-
T_{10}	5.61	5.87de	5.57b	4.83a	5.42c	5.66b	6.97*f	-	-
C.D. (0.05)	-	0.131	0.110	0.106	0.135	0.110	0.149	0.120	0.118
SEm ±	-	0.044	0.037	0.036	0.045	0.037	0.049	0.038	0.036

*Sampling was discontinued further as the sample exceeded critical moisture content (CMC-7.00%) at this stage.

(Means in the column followed by the same alphabet do not differ significantly by DMRT at 5%).

(T_1- Sandwich bag with Liner I: HMHDPE, T_2- Sandwich bag with Liner II: LDPE-HDPE-LDPE 3 layered film, T_3- Sandwich bag with Liner III: LDPE-EVOH-LDPE 5 layered film, T_4- PP woven sacks with Liner I: HMHDPE, T_5- PP woven sacks with Liner II: LDPE-HDPE-LDPE, T_6- PP woven sacks with LDPE-EVOH-LDPE, T_7- 4 ply Multiwall Paper Sack with 7 µ Aluminium Foil/poly Liner, T_8- 4 ply Multiwall Paper Sack with 12 µ MET PET/poly Liner, T_9- 2 ply Multiwall Paper Sack with 7 µ Aluminium Foil/poly Liner, T_{10}- 2 ply Multiwall Paper Sack with 12 µ MET PET/poly Liner).

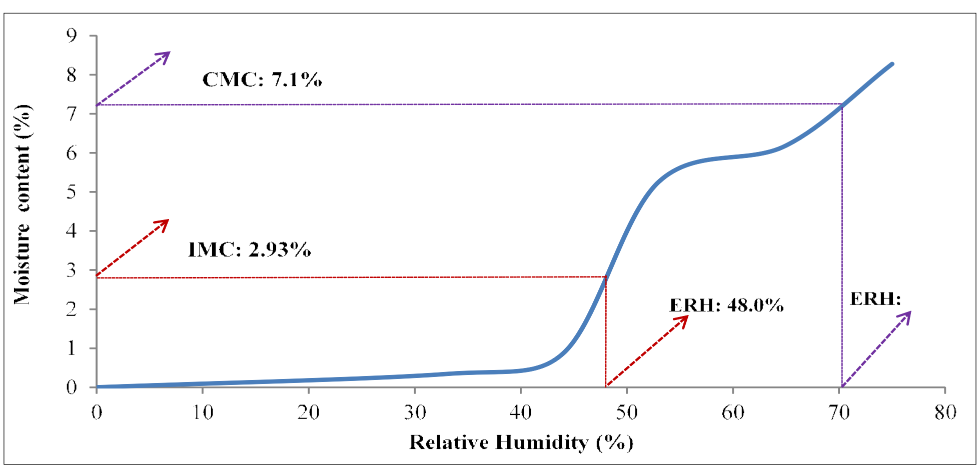

Fig 1: Sorption isotherm of orthodox tea at 27±2°C.

become mature (Balasooriya*et al*., 2019). Hence, low water-soluble ash content usually indicates an inferior tea (Adnan *et al*., 2013). Chung *et al*. (1998) reported positive association between ash content and keeping quality of the tea.

Total tannin content

The amount of total tannin content varied from 11.84-14.64 % during the entire storage period, as presented in Table 6. The tannin content is the most important chemical

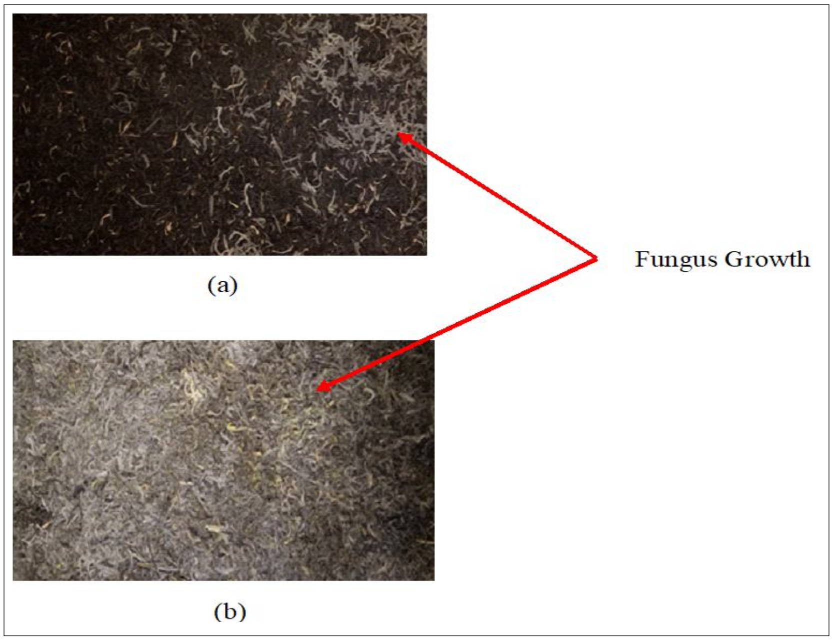

Fig 2: Fungus Development on orthodox Tea packed in (a) PP woven sack with Liner I: HMHDPE and (b) 2 ply Multiwall Paper Sack with MET PET Liner.

Table 6: Tannin content in orthodox tea during exposure period.

Packaging materials	Tannin content (%)								
	Days in storage								
	0	15	30	45	60	75	90	105	120
T_1	11.84	12.65ef	14.08e	11.92bc	12.60d	12.54c	14.38e	-	-
T_2	11.84	12.77f	14.64f	12.93e	13.44f	11.79a	13.46d	-	-
T_3	11.84	11.93a	13.42d	11.78ab	12.18b	12.59c	14.09e	12.43bc	11.76a
T_4	11.84	12.21bc	12.45c	11.86bc	11.76a	-	-	-	-
T_5	11.84	12.46d	11.78a	12.48d	12.18b	11.86a	-	-	-
T_6	11.84	12.24c	12.08b	11.67a	12.60d	12.54c	13.08c	12.17ab	11.76a
T_7	11.84	12.09b	11.65a	12.57d	12.18b	12.24b	12.67b	11.86a	11.76a
T_8	11.84	12.56de	12.43c	11.79abc	12.60d	11.96a	12.39b	12.73c	12.18a
T_9	11.84	12.31c	11.79a	12.58d	12.36c	11.87a	11.95a	12.59c	-
T_{10}	11.84	12.09b	12.34c	11.97c	13.12e	12.64c	11.86a	-	-
C.D. (0.05)	-	0.135	0.132	0.170	0.116	0.199	0.372	0.361	N.S
SEm ±	-	0.046	0.044	0.057	0.039	0.067	0.123	0.113	0.127

*Sampling was discontinued further as the sample exceeded critical moisture content (CMC-7.00%) at this stage.

(Means in the column followed by the same alphabet do not differ significantly by DMRT at 5%) N.S-Non significant.

(T_1- Sandwich bag with Liner I: HMHDPE, T_2- Sandwich bag with Liner II: LDPE-HDPE-LDPE 3 layered film, T_3- Sandwich bag with Liner III: LDPE-EVOH-LDPE 5 layered film, T_4- PP woven sacks with Liner I: HMHDPE, T_5- PP woven sacks with Liner II: LDPE-HDPE-LDPE, T_6- PP woven sacks with LDPE-EVOH-LDPE, T_7- 4 ply Multiwall Paper Sack with 7 μ Aluminium Foil / poly Liner, T_8- 4 ply Multiwall Paper Sack with 12 μ MET PET/ poly Liner, T_9- 2 ply Multiwall Paper Sack with 7 μ Aluminium Foil / poly Liner, T_{10}- 2 ply Multiwall Paper Sack with 12 μ MET PET/ poly Liner).

constituent which is responsible for the stimulating effect of tea. The variation in tannin content in Orthodox tea might be due to several factors such as maturity of the tea plant at the time of harvest, climatic conditions, agronomical practices and postharvest management. Another important factor is the processing of black tea. During the fermentation process, some of the tannins which are phenolic compounds undergo polymerization and/or degradation to other metabolites (Teshome 2019; Ramamoorthy and Bono, 2007; Rusak *et al*., 2008).

Sorption isotherm

The sorption isotherm of Orthodox tea was characterized by a sigmoid shape graph. The equilibrium relative humidity (ERH) was determined from the graph as represented in Fig 1. When the tea was manufactured and packed, the average initial moisture content (IMC) recorded was 2.93%. The critical moisture content (CMC) is the level of moisture content when the product just begins to deteriorate. As per FSSAI Regulations (2011), the critical moisture content for tea is 7.00%. The ERH for Orthodox tea at IMC and CMC were 48% and 70% respectively. This indicates that tea is extremely hygroscopic and picks up moisture when exposed to higher RH and the moisture pick up would be very rapid beyond 72% RH. Tea is hygroscopic in nature which has the ability to absorb or desorb moisture in response to temperature and RH of the atmosphere in its storage. This affinity of tea for moisture is caused by the hydroxyl groups accessible in the cell walls of tea leaves. The water which is adsorbed by sorption sites in amorphous areas of cellulose and hemicelluloses are present in the cell walls (Dmowski and Ruszkowska, 2018).

Transport worthiness test

The transport worthiness of ten selected packaging materials, neither showed rupture of the bag nor seepage of the tea sample from any of the sacks. Packaging plays a major role to protect the products from various transportation hurdles. Hence, the transport worthiness test predicts the stability of the transport pack.

CONCLUSION

The accelerated shelf life testing estimated the storage of Orthodox tea to be 60 to 105 days and thus, it can be estimated that the shelf life in normal condition (27±1 °C and 65±2% RH) would be 180 to 315 days. Based on this, it is concluded that out of 10 different options of packaging materials, the maximum anticipated shelf life of Orthodox tea at normal condition can be achieved by Sandwich bag with Liner III: LDPE-EVOH-LDPE, PP woven sacks with Liner III: LDPE-EVOH-LDPE, 4 ply Multiwall Paper Sack with 7 µ Aluminium Foil/poly Liner and 4 ply Multiwall Paper Sack with 12 µ MET PET/poly Liner.

Conflict of interest

All authors declared that there is no conflict of interest.

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