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ORIGINAL ARTICLE

Use of paprika oily extract as pre-extrusion colouring of rice extrudates: impact of processing and storage on colour stability

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Abstract Suitability of paprika oily extract as a pre-extrusion colouring of rice extrudate was evaluated as a function of extrusion parameters viz. moisture content, screw speed and die temperature. Most acceptable coloured rice extrudates in terms of colour and overall acceptability was achieved with addition of 3 % paprika oily extract and which is extruded at fixed conditions of 25 % feed moisture, 120 °C barrel temperature and 100 rpm screw speed. During extrusion, retention of red colour of paprika oily extract added rice extrudates increased with an increase in feed moisture and screw speed while decreased with an increase in barrel temperature. Present study was also undertaken to check effect of addition of butylated hydroxytoluene (BHT) on colour stability of coloured rice extrudates. Coloured rice extrudates were packed in polyethylene, metallised polyethylene and vacuum packaging material and subjected to storage studies for 90 days at 25 and 50 °C with 65 % relative humidity conditions. Retention of red colour (a*) of paprika oily extract added rice extrudates follows first order kinetics, showing a faster rate of degradation with half-life of 48 days when packed in metalized polyethylene and stored at higher temperature conditions.

Keywords Pre-extrusion colouring · Paprika · Storage stability · Degradation kinetics

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Introduction

Fast changing life style of the consumer demands convenience in terms of savings in time and energy. Development of ready to eat products adds convenience, saves time and labour. Extrusion cooking is a popular technology in food processing, provides hygienic products of standard and uniform quality with enhanced shelf life. It plays a key role as a continuous cooking, mixing and forming process (Gat and Ananthanarayan 2015a). Processing conditions used in extrusion cooking result in numerous chemical and structural changes in food like starch gelatinization, protein denaturation, vitamin and pigment degradation (Harper 1981). Generally, extruded products are not coloured, and are also flavoured post-extrusion. However the use of natural colours prior to extrusion cooking would not only add to visual appeal and acceptability, but could also form a suitable matrix for delivery of nutraceutical phytochemicals to consumers. This necessitates evaluation of stability of these phytochemicals.

With regard to choice and consumption of food, all human sensory perceptions are involved. Among them, vision is the most important one for selecting food and appreciating its quality. Colour is an intrinsic property of food. A colour change of food often is caused by a quality change. Colour is a vital quality attribute of foods, and plays an important role in sensory and consumer acceptance of products. Based on the origin, food colours can be classified as natural, nature identical and synthetic. There is an increasing demand for the use of natural colours as they are preferred in foods over the synthetic colours. The usage of colourants in foods and the level of incorporation are governed by the regulatory requirements of the individual countries. According to the Prevention of Food Adulteration Act (PFA 1994) in

India, eight synthetic pigments and 11 natural pigments are permitted in foods.

Paprika oil extract is gaining importance as an alternative to synthetic red colourants for food and pharmaceutical applications (Biacs et al. 1989). Paprika is an extract of the fruits of the genus Capsicum. Capsicums are a widely consumed natural foodstuff used as a vegetable, spice or colour. The variety used to manufacture paprika extract for food colouration is *Capsicum annuum L.* in which capsanthin and capsorubin are the main compounds responsible for the red colour. Extracts are slightly viscous, homogenous red liquids with good flow properties at room temperature and are used to obtain a deep red colour in any food that has a liquid/fat phase. Typical use levels are in the range of 10–60 mg/kg finished food, calculated as pure colouring matter (Anonymous 2008).

Stability of paprika oily extract is influenced by numerous factors, viz., pH, temperature, oxygen, water activity and light, and this has limited its use as food colourants. In order to ensure optimum pigment and colour retention in paprika oily extract supplemented foods, the time–temperature conditions during food manufacture must be strictly controlled. In addition, external factors during storage such as temperature, light and oxygen exposure need to be considered (Pruthi 2003).

Safety of synthetic colourants has been questioned in the past years, leading to a reduction in the number of permitted colourants. Interest in natural colourants has significantly increased mainly due to both legislative action, and consumer awareness and also their therapeutic or medical properties. To the best of our knowledge, stability of added paprika oily extract as pre-extrusion colouring has not yet been reported in literature. Hence in this study attempts were made to develop ready to eat coloured extrudate products from rice flour using natural colour such as paprika oily extract added before extrusion cooking as raw ingredient. This will economically beneficial to manufacture as it reduces one step in extrusion cooking and time of processing. Objective of the present study was to check effect of extrusion parameters (feed moisture, barrel temperature and screw speed) on colour stability of rice extrudates prepared by addition paprika oily extract prior to extrusion cooking.

Materials and methods

Materials used

Sample of low cost polished rice (*Oryza sativa*) was obtained from Rice Research Centre, Karjat, India. Clear dark red oily liquid paprika colourant which was nearly free of pungency and without rancidity with 0.935 g/cm^3 density and 200cp viscosity having colour value of 100000IC (international colour) units was procured from Valentine Agro Ltd., Mumbai, India. Packaging materials such as polyethylene, co-extruded metalized polyethylene and co-extruded vacuum pouch with thicknesses ranging from 0.25 to 0.30 mm was procured from Shako Flexipack Pvt. Ltd., Sion Mumbai, India.

Preparation of sample for extrusion cooking

Rice was ground in a laboratory scale hammer mill (W-series, Schutte-Buffalo Hammermill, LLC, NY, USA) and passed through 80 mesh (British standard) sieve. Blends with different proportion (w/w) of rice flour (RF) and paprika oily extract colourant (i.e. 100:0, 99:01, 97:03, 95:05, 93:07) were prepared and extruded under fixed conditions of 25 % feed moisture content, 120 °C die temperature and 100 rpm screw speed to get most acceptable sample. After standardizing paprika oily extract concentration in rice extrudate (most acceptable sample) were used for further study. In the further studies involving BHT addition, BHT was added at 0.003 % of sample mass (rice flour + paprika extract) and blended properly prior to extrusion cooking.

Extrusion cooking

Extrusion cooking was performed as suggested by Gat and Ananthanarayan (2015b). A laboratory-scale-co-rotating twin-screw extruder (KETSE 20/40 Brabender GmbH and Co. KG, Duisburg, Germany) with 20:1 length to diameter ratio was used for extrusion cooking. Extruder barrel consisted of four heating/cooling zones. Extruder was fitted with a circular die having nozzle of 2 mm diameter. Feed rate was kept constant at 14 kg/hr by using vertical dosing screw feeder (Brabender GmbH and Co. KG, Duisburg, Germany). Moisture content of rice:-paprika oily extract blend flour was estimated (AACC 1995) and later calculated amounts of water were sprayed onto each sample to achieve desired feed moisture content. After that, samples were packed in polythene bags and stored at 4 °C for overnight to reach homogeneous moisture distribution. Before extrusion cooking the feed was allowed to come to ambient temperature ($\approx 25 \pm 3$ °C). Effect of extrusion cooking conditions (screw speed, barrel temperature and feed moisture) were checked for colour degradation of most acceptable sample (rice:paprika oily extract colourant, 97:03) which was obtained from previous experimentation study. To check effect of extrusion cooking parameters, during extrusion cooking screw speed, barrel temperature and feed moisture was varied as 50–100 rpm, 100–120 °C and 20–25 % respectively.

Colour measurement and sensory analysis of rice extrudates prepared from rice:paprika oily extract blends

Colour measurement

Hunter colour parameters (L*, a*, b*) for raw formulations and coloured rice extrudates were measured as suggested by Gat and Ananthanarayan (2015c). A HunterLab colourimeter (LabScan XE, Hunter associates laboratory, Reston, VA, USA) coupled with EasyMatch QC software was used for colour measurement. In this colour space the colour points are characterized by three colour coordinates. L* is the lightness coordinate ranging from no reflection for black (L* = 0) to perfect diffuse reflection for white (L* = 100). a* is the 'redness' coordinate ranging from negative values for green to positive values for red. b* is the 'yellowness' coordinate ranging from negative values for blue to positive values for yellow. Numerical total colour difference (ΔE) was calculated as per equation given by Camire et al. (2002). Reported values of each sample were the average values of five replicates.

Sensory analysis

All dried rice extrudate samples with added paprika oily extract were prepared for sensory evaluation. Samples were evaluated by 20 semi-trained panelists (research students and staff members) from Department of Food Engineering, University Institute of Chemical Technology, Mumbai, India. They were asked to score their preferences for sensory attributes (appearance, colour, texture and overall acceptability) of the samples using nine-point hedonic scales, where 9 = extremely like and 1 = extremely dislike. Each panelist evaluated all samples (identified by unique three-digit codes) in a balanced sequential order. Training sessions were held until panel members could identify the same sample that was coded differently in a session.

Colour degradation analysis of rice extrudates prepared from rice:paprika oily extract blends after addition of BHT and use of different packaging materials at different storage conditions

The sample mass of 250 g of most acceptable coloured rice extrudates containing paprika oily extract (97:03) were packed in each polyethylene (PE), metalized polyethylene (MPE) and co-extruded vacuum pouch respectively. These coloured dry rice extrudates were stored at two different storage conditions as 25 and 50 °C with 65 % relative humidity and were evaluated for percent colour retention. During 90 days of storage study along with 65 % relative humidity 25 °C temperature was selected as ambient condition while 50 °C temperature was selected as to check effect of temperature above that of accelerated storage conditions. In similar manner effect of addition of BHT (0.003 %) on colour degradation of rice:paprika oily extract blend extrudates was also analyzed.

Kinetic modeling

Colour degradation kinetics of paprika oily extract added rice extrudates may be described by a zero or first order kinetic models, Eqs. (1) and (2) respectively.

$$C = C0 \pm k0t \quad (1)$$

$$C = C0 \exp(\pm k1t) \quad (2)$$

where *C* is the measured value of colour variables at time t, *C0* the initial value of colour variables at time zero, *t* the storage time, *k0* the zero-order kinetic constant (time^{-1}) and *k1* is the first-order kinetic constant (time^{-1}). Where (+) and (−) indicate formation and degradation of quality parameter respectively. Further, a semi-log plot of percent retention of colour vs. days (Cai et al. 1998) was prepared to obtain the rate constant (k) as the slope of the graph. Half-life ($t_{½}$), the time required for the red paprika oily extract colourant to decrease to 50 % of its initial colour was calculated from the rate constant as 0.693/k***.

Statistical analysis

Means and standard deviations of five replicates were determined for colour and sensory studied. Significant difference of mean values was assessed with one-way analysis of variance (ANOVA) followed by Duncan's LSD test using SPSS software at a significance level of ($P < 0.05$). Kinetics data were analyzed and the kinetic parameters were determined using 'Microsoft Excel' software (Version 16, Microsoft Corporation, Redmond, WA, USA).

Results and discussion

Standardization of paprika oily extracts concentration in coloured rice extrudates

Rice flour and paprika oily extract varied at different concentrations (100:00, 99:01, 97:03, 95:05, 93:07) was extruded under fixed conditions of 25 % feed moisture content, 120 °C die temperature and 100 rpm screw speed. From Table 1 it was observed that as the concentration of paprika oily extract increased from 1 to 7 %, lightness (L* value) of coloured rice extrudate were decreased

Table 1 Effect of addition of paprika oily extract on colour and overall acceptability of rice extrudates prepared under fixed extrusion conditions of 25 % feed moisture, 120 °C barrel temperature and 100 rpm screw speed

Rice:paprika oily extract concentration	L*	a*	b*	ΔE	Overall acceptability
100:00 (Control)	75.23 ± 0.01[a]	2.19 ± 0.02[e]	19.19 ± 0.01[e]	77.66 ± 0.01[a]	6.8 ± 0.13[d]
99:01	64.41 ± 0.01[b]	27.36 ± 0.02[d]	47.82 ± 0.04[d]	84.76 ± 0.04[d]	7.7 ± 0.26[b]
97:03	61.52 ± 0.03[c]	33.79 ± 0.04[c]	52.84 ± 0.03[c]	85.08 ± 0.05[c]	8.3 ± 0.21[a]
95:05	53.02 ± 0.02[d]	39.13 ± 0.05[b]	54.57 ± 0.06[b]	85.56 ± 0.03[b]	7.4 ± 0.24[c]
93:07	48.71 ± 0.01[e]	42.15 ± 0.06[a]	56.78 ± 0.03[a]	85.70 ± 0.01[a]	7.1 ± 0.17[cd]

All the values are mean ± SD of five replicates

Mean values with different superscripts on the same column differ significantly (Duncan's LSD test, $P < 0.05$)

significantly ($P < 0.05$). While redness (a* value) and total colour (ΔE) of paprika oily extract added rice extrudate were significantly increased. Maximum lightness (L* value) and minimum redness (a* value) as well as total colour (ΔE) was observed for control rice extrudate (100:00) in which paprika oily extract were not added. Sensory scores obtained for different concentrated coloured rice extrudates on day 0 were 6.8, 7.7, 8.3, 7.4 and 7.1 respectively (Table 1). From these results it can be seen that all the samples received scores above 6.0, indicating all the samples to have a good sensory acceptability. Sample that was extruded with 3 % paprika oily extract colourant was the most acceptable in terms of colour and overall acceptability and hence was used for further studies. Above 3 % paprika oily extract concentration, colour of rice extrudates was darker which reduced the overall acceptability.

Standardization of extrusion cooking parameters for preparation of coloured rice extrudates

Colour properties

Colour characteristics of paprika oily extract added rice extrudates were measured in terms of L*, a*, b* and ΔE value. Table 2 shows the effect of different extrusion cooking parameters (feed moisture, barrel temperature and screw speed) on the colour degradation (L* value) of paprika oily extract added rice extrudates. L* value (lightness) of coloured rice extrudates increased significantly ($P < 0.05$) with an increase in temperature from 100 to 120 °C. While L* value (lightness) of coloured rice extrudates decreased significantly ($P < 0.05$) with an increase in feed moisture content from 20 to 25 %. From Table 2 it was observed that maximum lightness (L* value) was found at high barrel temperature (120 °C) and low screw speed (50 rpm) conditions. From this study it can be concluded that there was loss in intensity of coloured rice extrudate as L* value increased significantly ($P < 0.05$) while a* value decreased with an increase in barrel temperature. Similar results of negative effect of extrusion temperature on L* value of banana flour added extrudates were observed by Kaur et al. (2015a, b). Retention of added colour increased with an increase in moisture content (20–25 %) and screw speed (50–100 rpm).

The a* value (+'a' value indicates redness and −'a' value indicates greenness) of paprika oily extract added rice extrudates increased with an increase in moisture content and screw speed while it was decreased with an increase in die temperature. Table 2 shows the effect of different extrusion cooking parameters on colour degradation (a* value) of paprika oily extract added rice extrudates. a* value ranged from 31.15 to 34.95 for paprika oily extract added coloured rice extrudates, representing as a function of temperature and feed moisture. Residence time of raw material decreased as screw speed increased, thus resulting in more retention of the colour. Decrease in redness of coloured rice extrudates with increasing temperature was induced by pigment destruction as natural pigments are sensitive to thermal processing and these limiting its use. Similar result of paprika oily extract supplemented colourant degradation due to temperature was indicated by several researchers (Minguez-Mosquera and Jaren-Galan 1995; Jaren-Galan and Minguez-Mosquera 1999; Perez-Galvez et al. 2000).

Effect of different extrusion cooking process parameters on the b* value (+'b' value indicates yellowness and −'b' value indicates blueness) of paprika oily extract added rice extrudates was shown in Table 2. b* value of paprika oily extract added coloured rice extrudates was not significantly affected by extrusion cooking parameters. b* value of paprika oily extract added coloured rice extrudates increased with an increase in temperature and screw speed, while decreased with increase in feed moisture as the result of Maillard reactions product formation. Result indicates that the sample having maximum a* value had lower b* value, suggesting that as the redness of samples increased

Table 2 Effect of extrusion cooking parameters (feed moisture, barrel temperature and screw speed) on colour properties (L*, a*, b* and ΔE) of extrudate prepared from rice:paprika oily extract (97:03)

Barrel temp (°C)/screw speed (rpm)	Feed moisture 20 %				Feed moisture 25 %			
	L*	a*	b*	ΔE	L*	a*	b*	ΔE
100/50	59.82 ± 0.02[c]	33.26 ± 0.04[b]	51.42 ± 0.02[d]	86.35 ± 0.04[d]	54.21 ± 0.02[c]	34.89 ± 0.03[a]	50.59 ± 0.03[c]	79.62 ± 0.06[c]
100/100	58.52 ± 0.0[d]	33.48 ± 0.02[a]	51.47 ± 0.02[c]	87.03 ± 0.07[c]	51.95 ± 0.01[d]	34.94 ± 0.05[a]	50.61 ± 0.01[bc]	77.21 ± 0.07[d]
120/50	60.39 ± 0.03[a]	31.15 ± 0.02[d]	51.53 ± 0.02[b]	88.81 ± 0.06[b]	59.88 ± 0.01[a]	32.14 ± 0.03[c]	50.63 ± 0.04[b]	88.24 ± 0.06[a]
120/100	60.36 ± 0.01[b]	31.23 ± 0.02[c]	51.60 ± 0.03[a]	89.96 ± 0.07[a]	57.61 ± 0.01[b]	32.38 ± 0.04[b]	50.68 ± 0.02[a]	86.03 ± 0.08[b]

All the values are mean ± SD of five replicates

Mean values with different superscripts on the same column differ significantly (Duncan's LSD test, $P < 0.05$)

Table 3 Effect of extrusion cooking parameters (feed moisture, barrel temperature and screw speed) on sensory properties of extrudate prepared from rice:paprika oily extract (97:03)

Extrusion cooking conditions (feed moisture/barrel temperature/screw speed)	Appearance	Colour	Texture	Overall acceptability
20 %/100 °C/50 rpm	7.9 ± 0.3[b]	8.5 ± 0.3[ab]	7.5 ± 0.3[cd]	7.9 ± 0.4[b]
20 %/100 °C/100 rpm	8.5 ± 0.3[a]	8.9 ± 0.1[a]	8.1 ± 0.1[ab]	8.5 ± 0.3[a]
20 %/120 °C/50 rpm	8.4 ± 0.2[a]	8.0 ± 0.3[c]	7.9 ± 0.2[bc]	7.1 ± 0.2[c]
20 %/120 °C/100 rpm	7.0 ± 0.3[c]	8.0 ± 0.2[c]	7.0 ± 0.3[e]	7.3 ± 0.2[c]
25 %/100 °C/50 rpm	6.4 ± 0.1[d]	6.5 ± 0.3[e]	8.5 ± 0.3[a]	7.1 ± 0.2[c]
25 %/100 °C/100 rpm	7.0 ± 0.4[c]	8.4 ± 0.4[bc]	6.0 ± 0.2[g]	6.9 ± 0.2[c]
25 %/120 °C/50 rpm	6.5 ± 0.3[cd]	7.0 ± 0.1[d]	6.5 ± 0.4[f]	6.4 ± 0.3[d]
25 %/120 °C/100 rpm	6.9 ± 0.3[c]	6.4 ± 0.2[e]	7.3 ± 0.3[de]	7.0 ± 0.2[c]

All the values are mean ± SD of five replicates

Mean values with different superscripts on the same column differ significantly (Duncan's LSD test, $P < 0.05$)

its yellowness decreased and vice versa. Similar results of decrease in b* value (yellowness) of different bran extrudates with increase in moisture content was observed by Kaur et al. (2015a, b).

Sensory properties

All paprika oily extract added rice extrudates were evaluated for sensory attributes such as appearance, colour, texture and overall acceptability and their sensory scores are summarized in Table 3. From these results it can be seen that all the sensory attributes received scores above 6.0, suggesting that coloured rice extrudates with good sensory acceptability can be produced by addition of paprika oily extract colourant prior to extrusion cooking. Noodle sample that was extruded at 20 % feed moisture, 100 °C die temperature and 100 rpm was most acceptable in terms of appearance, colour, texture and overall acceptability. Most acceptable rice extrudate having 3 % paprika oily extract was used for further colour degradation studies (to check effect of different extrusion cooking conditions). Photographic images of optimized rice extrudate sample (packed in vacuum packaging, stored at 25 °C with 65 % relative humidity) as a function of storage time are shown in Fig. 1.

Kinetics of colour degradation of rice extrudates prepared with addition of BHT (packed and stored at different conditions)

Most acceptable paprika oily extract added rice extrudates were packed in polyethylene, metalized polyethylene and vacuum pouch and stored at different storage conditions for 90 days. For the mathematical modeling of colour change of rice extrudates, zero-order and first-order kinetic models were used (Figs. 2, 3, 4 and 5). It was observed that the colour degradation (L*) with or without addition of BHT followed a zero-order kinetic model (Figs. 2 and 3); on other hand, colour degradation (a*) with or without addition of BHT was fitted to the first-order kinetic model (Figs. 4 and 5). The estimated kinetic parameters of these models and the statistical values of coefficients of determination R^2 are represented in Tables 4 and 5.

Rice extrudates packed in all packaging materials at both storage conditions (25 °C and 50 °C with 65 % relative humidity) showed an increase in lightness. Rice

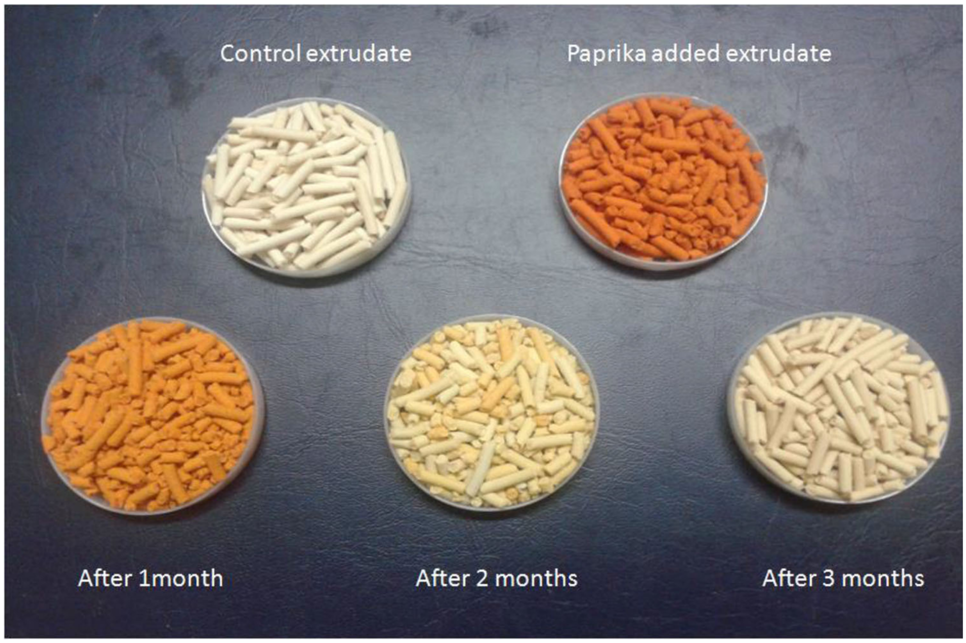

Fig. 1 Photographic images of control (without addition of paprika) and optimized rice:paprika blend extrudate (packed in vacuum packaging, stored at 25 °C with 65 % relative humidity) as a function of storage time indicating *colour* degradation

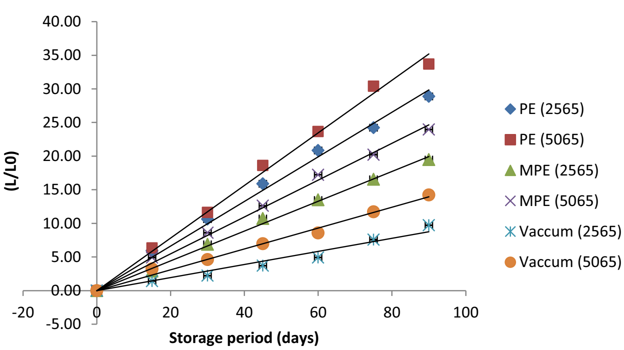

Fig. 2 Kinetics of *colour* (L*) degradation of rice extrudates prepared without addition of BHT (packed and stored in different conditions) as a function of storage time for Zero order model

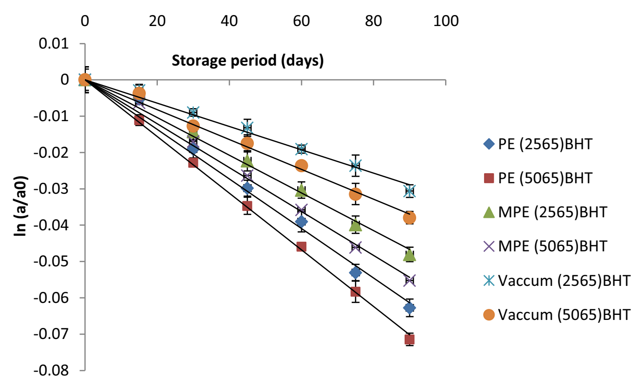

Fig. 4 Kinetics of *colour* (a*) degradation of rice extrudates prepared with addition of BHT (packed and stored in different conditions) as a function of storage time for First order model

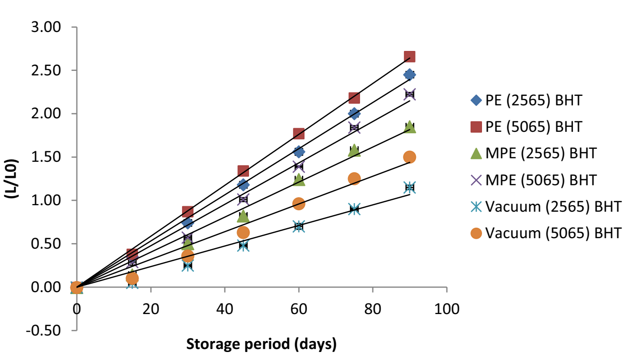

Fig. 3 Kinetics of *colour* (L*) degradation of rice extrudates prepared with addition of BHT (packed and stored in different conditions) as a function of storage time for Zero order model

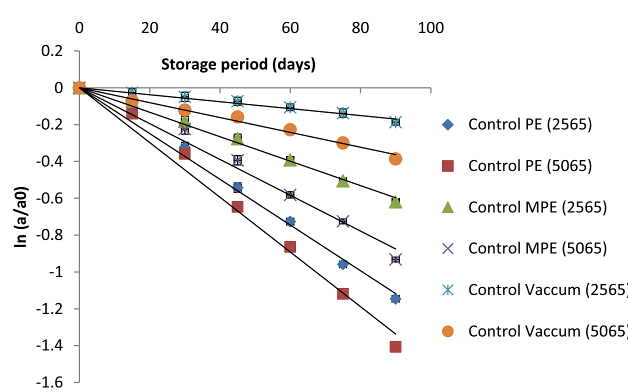

Fig. 5 Kinetics of *colour* (a*) degradation of rice extrudates prepared without addition of BHT (packed and stored in different conditions) as a function of storage time for First order model

Table 4 Rate constant (k), correlation coefficient (R^2) and half-life ($t_{1/2}$) for colour (L*) degradation of rice extrudates prepared with/without addition of BHT (packed and stored in different conditions)

	Rate constant (k) ($time^{-1}$)	Correlation coefficient (R^2)	Half-life ($t_{1/2}$) (days)	Colour (L*) degradation (%)
Without addition of BHT				
PE (2565)	0.221	0.9965	3	28.23
PE (5065)	0.265	0.9883	3	31.67
MPE (2565)	0.333	0.9677	2	36.22
MPE (5065)	0.389	0.9939	2	40.02
Vacuum (2565)	0.0973	0.9615	7	16.39
Vacuum (5065)	0.139	0.9881	5	21.06
With addition of BHT				
PE (2565)	0.0191	0.988	36	3.52
PE (5065)	0.0266	0.9978	26	4.93
MPE (2565)	0.0239	0.9900	29	4.47
MPE (5065)	0.0294	0.9991	24	5.36
Vacuum (2565)	0.012	0.9656	58	2.31
Vacuum (5065)	0.016	0.9757	43	3.02

PE Polyethylene, *MPE* Metalized polyethylene, 2565: 25 °C and 65 % relative humidity, 5065: 50 °C and 65 % relative humidity

Table 5 Rate constant (k), correlation coefficient (R^2) and half-life ($t_{1/2}$) for colour (a*) degradation of rice extrudates prepared with/without addition of BHT (packed and stored in different conditions)

	Rate constant (k) ($time^{-1}$)	Correlation coefficient (R^2)	Half-life ($t_{1/2}$) (days)	Colour (a*) degradation (%)
Without addition of BHT				
PE (2565)	0.006	0.9935	103	46.14
PE (5065)	0.012	0.9902	56	68.19
MPE (2565)	0.009	0.9833	71	60.64
MPE (5065)	0.014	0.9912	48	72.97
Vacuum (2565)	0.001	0.9775	365	17.06
Vacuum (5065)	0.004	0.9872	173	31.98
With addition of BHT				
PE (2565)	0.0005	0.9881	1386	4.69
PE (5065)	0.0007	0.989	990	6.08
MPE (2565)	0.0006	0.9964	1155	5.37
MPE (5065)	0.0008	0.9969	866	7.15
Vacuum (2565)	0.0003	0.9879	2310	3.01
Vacuum (5065)	0.0004	0.9917	1733	3.72

PE Polyethylene, *MPE* Metalized polyethylene, 2565: 25 °C and 65 % relative humidity, 5065: 50 °C and 65 % relative humidity

extrudates without addition of BHT which was packed in metalized polyethylene showed maximum (40 %) increase in lightness (decrease in colour intensity) with half-life of 2 days (Table 4). BHT added rice extrudate which was packed in vacuum packaging showed minimum (16 %) increase in lightness (decrease in colour intensity) indicating maximum colour stability having half-life of 7 days. Temperature has significant effect on lightness for vacuum packaged rice extrudates with or without addition of BHT. All rice extrudate samples stored for 90 days at different packaging and storage conditions demonstrated linear nature of the graph indicating the increase in percent degradation of colour (lightness) to follow zero order kinetics.

Rice extrudates packed in packaging materials (polyethylene, metalized polyethylene and co-extruded vacuum pouch) at both storage conditions (25 °C with and 50 °C with 65 % relative humidity) showed decrease in redness. Rice extrudates without addition of BHT which was packed in metalized polyethylene showed maximum (72 %) decrease of redness (degradation of colour) with half-life of 48 days (Table 5). BHT added rice extrudates was packed in vacuum packaging showed minimum (3 %) decrease of redness (degradation of colour) indicating maximum colour stability. Temperature had significant effect on redness for vacuum packaged rice extrudates with and without addition of BHT. Rice extrudates stored for 90 days at different packaging and storage conditions demonstrated linear nature of the graph indicating the decrease in percent retention of colour (redness) to follow first order kinetics. This work is in agreement with results reported by Sowbhagya et al. (2005). They reported that natural colour curcumin follows first order kinetics for colour retention during storage study of 10 weeks in extruded product.

Conclusion

Retention of redness of coloured rice extrudates increased with an increase in feed moisture content and screw speed while it was decreased with an increase in die temperature. Addition of 0.003 % BHT in coloured rice extrudate reduces the colour degradation by almost 40 % when used as pre-extrusion colouring additive. Study highlights on the use of paprika oily extract added colourant for safe and attractive red coloured rice extrudates, and could create a commercial impact.

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Compliance with ethical standards

Conflict of interest Authors don't have any conflict of interest.

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