Gum cordia as carrier of antioxidants: effects on lipid oxidation of peanuts

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Abstract Performance of antioxidants is improved by incorporating them into polymer matrix such as polysaccharides based edible coatings. Gum cordia, an anionic polysaccharide extracted from the fruits of *Cordia.myxa* could be used as carrier of antioxidants by virtue of its strong adhering and emulsifying properties. This study aimed to explore the potential of gum cordia as carrier of antioxidants when applied as edible coating on peanuts. Gum Cordia was compared with carboxymethyl cellulose (CMC) in delivering of antioxidants: butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and ascorbic acid (AA). Coated and uncoated peanuts were stored at 35 °C for 126 days and coating carrier effectiveness was measured by following lipid oxidation using chemical parameters (peroxide value and thiobarbituric acid reactive species) and sensory evaluation (oxidized flavor). Significant differences ($p < 0.05$) between coated and uncoated samples were observed. Gum cordia was found better than CMC to deliver the antioxidants. Gum cordia based coating in combination with BHA/BHT exhibited highest protection (290 % higher shelf life than control) based on peroxide value ($40 \text{ meq.O}_2 \text{ kg}^{-1}$) followed by gum cordia plus BHT (244 %), gum cordia plus BHA (232 %), CMC plus BHA/BHT (184 %), CMC plus BHA (139 %), CMC plus BHT (119 %), gum cordia plus AA (96 %) and CMC plus AA (46 %).

Keywords Gum cordia · Peanuts · Shelf life · Edible coating

Introduction

Efforts to use the edible films and coatings in food processing and preservation have recently increased since they have

several advantages over traditional systems. They are biodegradable thus environment friendly (Tharanathan 2003), economically viable (Pandey et al. 2010), maintain the quality of the product even under ordinary storage conditions (Bisen et al. 2011) and provide a device to carry the functional ingredients.

The functional ingredients such as antimicrobial agents, antioxidants, nutrients and flavors, when applied directly to food surface can be neutralized or rapidly diffused into the bulk of the food (Mastromatteo et al. 2010). Incorporation of active compounds in polymeric structure is a valid solution of these problems (Lopez-Rubio et al. 2004). Inclusion of these compounds in edible coatings concentrates them at the surface. Since most of the deterioration particularly of oxidative nature is initiated from the surface therefore additives added edible coatings provide the protection where required and thus minimized the amount of additives required (Guillard et al. 2009).

Several studies have been reported on the use of natural polymers as carrier of food additives via coatings. Sorbates in kappa-carrageenan, tapioca starch and wheat gluten (Choi et al. 2005; Han and Floros 1998; Redl et al. 1996), ascorbic acid and ascorbyl palmitate in whey protein isolate (Han et al. 2008; Min and Krochta 2007), and α -tocopherol in carboxymethyl cellulose (CMC) are few examples.

Gum cordia is an anionic polysaccharide (Benhura and Chidewe 2004) extracted from the fruits of *Cordia.myxa* (Fam: Boraginaceae) which is a small size deciduous tree native to Indian subcontinent. The fruit of *C.myxa* is commonly known as *lassora*. People in this region consume fresh ripe fruits while unripe fruits are also used as vegetable and for making pickles (Siddiqui et al. 2006). The mucilaginous extract of the fruit has strong adhesion properties and is used for pasting sheets of papers and cardboards etc. The gum has been reported to be an excellent

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Table 1 Coating treatments used in this study

Treatment code	Coating material	Antioxidant	Concentration ^a (mg kg ⁻¹)
CoBABT	Gum Cordia	BHA+BHT	100
CoBHT	Gum Cordia	BHT	100
CoBHA	Gum Cordia	BHA	100
CoAA	Gum Cordia	Ascorbic acid	1000
CmBABT	Carboxymethyl cellulose	BHA+BHT	100
CmBHT	Carboxymethyl cellulose	BHT	100
CmBHA	Carboxymethyl cellulose	BHA	100
CmAA	Carboxymethyl cellulose	Ascorbic acid	1000
Control	None	None	NA ^b

^a Concentration based on solution^b NA Not Applicable

emulsifier and tablet binder (Dinda and Mukharjee, 2009). Adhesion and cohesion properties of this gum indicate its suitability as a carrier of food additives in edible coatings (Guilbert et al. 1996).

Peanuts, being high in total and unsaturated fats while low in indigenous antioxidants have been used as a model system for evaluation of different strategies to retard the lipid oxidation including edible coatings (Mate et al. 1996; Ahmed and Young 1982).

The objective of this study was to evaluate the antioxidant carrying ability of gum coardia in edible coatings. Butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and ascorbic acid (AA) were incorporated into gum cordia and then coated on peanuts. The effectiveness was measured by following the lipid oxidation parameters during storage. The study was conducted in comparison with previously reported polymer CMC.

Materials and methods

Sodium metabisulfite, BHA, BHT, glycerol and ascorbic acid were purchased from Sigma (Sigma–Aldrich GmbH, Sternheim, Germany). Carboxymethyl cellulose (CEKOL 30000G3®) was purchased from CP Kelco, Surrey, UK. All other chemicals used were of analytical reagent grade.

Fresh fruits of *C. myxa* were collected from the Karachi region during June 2010. Taxonomical identification was established by Mr. Jan-e-Alam, Department of Botany, University of Karachi (voucher specimen-G.H. No: 85852).

Mature pods of “Golden” variety of peanuts were provided by Barri Research Institute Chakwal, Punjab, Pakistan. The raw peanuts were visually inspected, sorted and cleaned for any physical impurities. The nuts were manually separated from the pod shells. The peanuts were dry-roasted at 141 °C for 15 min in a laboratory electric oven with intermittent manual stirring (Megahed 2001).

Preparation of coating solutions

The extraction of gum cordia and preparation of its solution was done by the method of Haq et al. (2012). The CMC solution was prepared as described by Trezza and Krochta (2000). Briefly, 10 g of CMC powder was added slowly into 800 mL of water with gentle stirring. Synthetic antioxidants, BHA and BHT, were first mixed into glycerol which was then added at a rate of 200 g kg⁻¹ of polymer weight i.e. CMC or gum cordia solution. Ascorbic acid, in solution, form was added slowly in portions into gum solutions and pH was adjusted to 7.0 using 0.1 N NaOH between intermediate stages, then glycerol at a rate of 200 g kg⁻¹ was added. The polymers concentration was finally adjusted to 10 g L⁻¹ using water. Solutions were degassed before use.

Coating and storage of peanuts

Coating treatments used in this study is mentioned in Table 1. Coating and storage method described previously by our group (Haq et al. 2012) was used in this study. Samples were chemically and sensory evaluated just after coating and then after periodic intervals of 21 days during 126 days of storage.

Table 2 Coating efficiency as determined by weight gain and antioxidant measurements ^a

Coating	Weight gain (g/100gm)	C.V (%)	Antioxidant (mg kg ⁻¹)
CoBABT	0.336±0.0030 ^b	10.84	62.21±2.487 ^c
CoBHT	0.339±0.0031 ^b	11.33	63.87±3.004 ^c
CoBHA	0.332±0.0031 ^b	11.50	65.09±2.852 ^c
CoAA	0.556±0.0062 ^a	10.67	289.34±25.565 ^a
CmBABT	0.150±0.0025 ^d	20.62	26.09±1.435 ^d
CmBHT	0.153±0.0024 ^d	19.61	27.89±1.540 ^d
CmBHA	0.152±0.0023 ^d	18.34	24.04±1.650 ^d
CmAA	0.290±0.0057 ^c	19.23	141.689±13.674 ^b

^a Data is displayed as Mean±SEM, *n*=150 for weight gain, *n*=3 for antioxidant, Means with different superscript alphabets in the columns are significantly different (*P*<0.05)

Table 3 Effect of different coatings on peroxide value (meq.O₂ kg⁻¹) of peanuts during storage ^a

Time (Days)	CoBABT	CoBHT	CoBHA	CmBABT	CmBHA	CmBHT	CoAA	CmAA	Control
0	1.0±0.01 ^{a,1}	1.1±0.03 ^{a,1}	1.1±0.05 ^{a,1}	1.0±0.02 ^{a,1}	1.0±0.02 ^{a,1}	1.0±0.04 ^{a,1}	1.2±0.02 ^{a,1}	1.1±0.05 ^{a,1}	1.0±0.03 ^{a,1}
21	1.2±0.02 ^{a,1}	1.3±0.28 ^{a,1}	1.3±0.06 ^{ab,1}	2.6±0.09 ^{ab,2}	4.8±0.35 ^{b,3}	5.4±0.30 ^{b,3}	4.6±0.71 ^{b,3}	9.6±0.83 ^{b,4}	14.9±0.27 ^{b,5}
42	1.4±0.01 ^{a,1}	1.4±0.04 ^{a,1}	2.2±0.31 ^{b,2}	3.4±0.01 ^{b,3}	7.0±0.33 ^{c,4}	9.7±0.53 ^{c,5}	8.8±1.39 ^{c,5}	21.0±1.73 ^{c,6}	28.1±0.34 ^{c,7}
63	1.5±0.19 ^{a,1}	1.5±0.21 ^{a,1}	3.4±0.16 ^{c,2}	6.0±0.35 ^{c,3}	8.7±0.72 ^{c,4}	12.9±1.29 ^{d,5}	15.2±0.64 ^{d,6}	33.2±1.37 ^{d,7}	56.5±0.35 ^{d,8}
84	2.3±0.11 ^{b,1}	2.1±0.53 ^{a,1}	4.4±0.28 ^{d,2}	11.4±0.93 ^{d,3}	20.5±0.73 ^{d,4}	26.2±0.40 ^{e,5}	29.4±1.15 ^{e,6}	56.5±1.40 ^{e,7}	107.5±0.28 ^{e,8}
105	6.6±0.47 ^{c,1}	9.8±2.49 ^{b,1}	13.5±0.26 ^{c,2}	25.1±0.80 ^{e,3}	36.8±1.10 ^{e,4}	45.6±0.56 ^{f,5}	52.6±1.73 ^{f,6}	81.2±1.92 ^{f,7}	123.8±0.14 ^{f,8}
126	16.4±0.37 ^{d,1}	21.9±1.44 ^{c,2}	24.5±0.62 ^{f,3}	35.1±0.85 ^{f,4}	51.4±0.78 ^{f,6}	57.5±0.06 ^{g,7}	87.5±1.60 ^{g,8}	114.1±2.40 ^{g,9}	43.0±0.07 ^{g,5}

Means with different superscript alphabets in the columns and number in the rows are significantly different ($P < 0.05$)

CoBABT Gum cordia+BHA/BHT, *CoBHT* Gum cordia+BHT, *CoBHA* Gum cordia+BHA, *CmBABT* CMC+BHA/BHT, *CmBHT* CMC+BHT, *CmBHA* CMC+BHA, *CoAA* Gum cordia+ascorbic acid, *CmAA* CMC+ascorbic acid

^a Data is displayed as Means±Standard Deviation, $n = 3$

Chemical methods

The chemical analyses were performed on the oil extracted from samples. The oil was extracted as described by Haq et al. (2012). Peroxide value (PV) was determined by the IUPAC standard procedure (IUPAC 1987). The spectrophotometric method described by Nepote et al. (2006) was used for measurement of thiobarbituric acid reactive substances (TBARS). Synthetic antioxidants BHA and BHT were measured using spectrophotometric method as described by Prasad et al. (1987). Ascorbic acid was measured by AOAC standard procedure (AOAC 2002).

Sensory analysis

Oxidized flavor intensity was determined by sensory evaluation scheme as described by Plemmons and Resurreccion (1998) and others (Nepote et al. 2006; Grosso and Resurreccion 2002).

Statistical analysis

The experiment was performed in three replicate. Data was analyzed using statistical package for social scientists (SPSS version 17). Analysis of variance (ANOVA) followed by Duncan multiple range test was used to distinguish the treatments ($p < 0.05$). Time course data was fitted on second order polynomial equation using regression analysis. Pearson's correlation coefficient was used to establish the relations between and among the sensory and chemical parameters.

Results and discussion

In preliminary studies, solutions of different concentration of polymers ranging from 2.5gm L⁻¹ to 20 g L⁻¹ were prepared and coated on peanuts. However, solutions below 10 g L⁻¹ were not coated evenly due to low viscosity while solutions above 10 g L⁻¹ were too thick and resulted in peanuts of

Table 4 Effect of different coatings on TBRAS value of peanuts^a

Time (Days)	CoBABT	CoBHT	CoBHA	CmBABT	CmBHA	CmBHT	CoAA	CmAA	Control
0	0.1±0.02 ^{a,1}	0.2±0.02 ^{a,1}	0.2±0.02 ^{a,1}	0.1±0.01 ^{a,1}	0.2±0.02 ^{a,1}	0.1±0.01 ^{a,1}	0.2±0.09 ^{a,1}	0.2±0.03 ^{a,1}	0.1±0.01 ^{a,1}
21	0.2±0.06 ^{a,1}	0.3±0.12 ^{a,1}	0.2±0.02 ^{a,1}	0.3±0.01 ^{a,1}	0.2±0.02 ^{a,1}	0.3±0.02 ^{a,1}	0.4±0.01 ^{a,1}	0.4±0.08 ^{a,1}	0.4±0.02 ^{a,1}
42	0.2±0.01 ^{a,1}	0.5±0.35 ^{a,1}	0.9±0.32 ^{ab,12}	1.0±0.29 ^{ab,12}	1.5±0.27 ^{b,2}	1.7±0.22 ^{ab,2}	1.5±0.09 ^{ab,2}	5.2±0.89 ^{b,3}	9.2±0.24 ^{b,4}
63	0.5±0.17 ^{b,1}	0.7±0.19 ^{a,1}	1.2±0.35 ^{ab,1}	1.4±0.29 ^{b,1}	1.9±0.38 ^{b,1}	2.2±0.31 ^{ab,12}	3.0±0.28 ^{b,2}	9.1±0.91 ^{b,3}	16.5±2.01 ^{c,4}
84	0.5±0.09 ^{b,1}	1.3±0.88 ^{a,12}	2.2±0.74 ^{bc,123}	2.7±0.51 ^{c,123}	4.0±0.53 ^{c,23}	4.5±0.53 ^{b,3}	5.1±0.80 ^{c,3}	15.6±1.17 ^{c,4}	25.5±2.08 ^{d,5}
105	0.7±0.13 ^{b,1}	1.4±0.49 ^{a,1}	3.4±0.55 ^{c,2}	6.6±0.15 ^{d,3}	9.7±0.06 ^{d,4}	14.6±1.29 ^{e,5}	14.4±0.91 ^{d,5}	32.1±2.09 ^{d,6}	55.8±0.55 ^{e,7}
126	1.4±0.04 ^{c,1}	2.8±0.17 ^{b,1}	6.0±0.48 ^{d,2}	10.8±0.43 ^{e,3}	16.3±0.71 ^{e,4}	20.8±2.30 ^{d,5}	27.4±0.94 ^{e,6}	59.2±2.11 ^{e,7}	65.3±0.10 ^{f,8}

Means with different superscript alphabets in the columns and number in the rows are significantly different ($P < 0.05$).

CoBABT Gum cordia+BHA/BHT, *CoBHT* Gum cordia+BHT, *CoBHA* Gum cordia+BHA, *CmBABT* CMC+BHA/BHT, *CmBHT* CMC+BHT, *CmBHA* CMC+BHA, *CoAA* Gum cordia+ascorbic acid, *CmAA* CMC+ascorbic acid

^a Data is displayed as Means±Standard Deviation, $n = 3$

Table 5 Effect of different coatings on oxidized flavor ratings of peanuts^a

Time (Days)	CoBAPT	CoBHT	CoBHA	CmBAPT	CmBHA	CmBHT	CoAA	CmAA	Control
0	4.8±0.54 ^{a,1}	5.8±0.82 ^{a,1}	5.3±0.89 ^{a,1}	5.0±0.76 ^{a,1}	5.0±0.87 ^{a,1}	5.0±0.67 ^{a,1}	4.9±0.51 ^{a,1}	4.6±0.6 ^{a,1}	4.3±0.82 ^{a,1}
21	6.2±0.89 ^{a,1}	6.1±1.22 ^{a,1}	6.1±1.28 ^{a,1}	6.5±1.09 ^{a,1}	7.8±1.09 ^{ab,1}	7.5±1.09 ^{a,1}	6.4±0.50 ^{a,1}	8.3±1.2 ^{b,1}	8.5±1.15 ^{a,1}
42	7.5±1.21 ^{a,1}	6.1±0.95 ^{a,1}	6.0±0.76 ^{a,1}	6.9±0.84 ^{a,1}	7.4±1.24 ^{ab,12}	7.7±1.26 ^{a,12}	10.1±0.70 ^{b,2}	14.1±0.8 ^{b,3}	14.9±1.23 ^{b,3}
63	7.3±0.54 ^{a,1}	7.2±0.92 ^{a,1}	7.4±0.97 ^{ab,1}	7.8±1.24 ^{a,1}	7.7±1.20 ^{ab,1}	8.4±1.14 ^{a,1}	11.9±0.81 ^{b,2}	20.0±0.8 ^{b,3}	19.7±1.42 ^{b,3}
84	7.5±1.25 ^{a,1}	7.4±1.01 ^{a,1}	8.9±1.39 ^{bc,1}	8.3±0.96 ^{a,1}	10.4±0.94 ^{b,12}	13.4±1.01 ^{b,2}	13.0±0.62 ^{b,2}	35.0±1.9 ^{d,3}	61.8±1.97 ^{c,4}
105	7.9±0.78 ^{ab,1}	7.8±0.86 ^{a,1}	10.3±1.43 ^{bc,12}	13.0±0.95 ^{b,2}	18.4±1.07 ^{c,3}	27.2±1.56 ^{c,4}	35.1±1.43 ^{c,5}	80.6±2.1 ^{c,6}	93.4±1.27 ^{d,7}
126	11.0±1.42 ^{b,1}	12.5±1.35 ^{b,1}	13.1±1.10 ^{c,1}	21.9±1.52 ^{c,2}	35.7±2.48 ^{d,3}	39.6±1.64 ^{d,3}	60.2±2.19 ^{d,4}	96.1±1.8 ^{e,5}	NP

Means with different superscript alphabets in the columns and number in the rows are significantly different ($P < 0.05$)

CoBAPT Gum cordia+BHA/BHT, *CoBHT* Gum cordia+BHT, *CoBHA* Gum cordia+BHA, *CmBAPT* CMC+BHA/BHT, *CmBHT* CMC+BHT, *CmBHA* CMC+BHA, *CoAA* Gum cordia+ascorbic acid, *CmAA* CMC+ascorbic acid

^a Data is displayed as Means±Standard Deviation, $n=9$

objectionable coating layer. Therefore, 10 g L⁻¹ concentration was used in this study. Different concentrations of antioxidants were also tried. In case of AA, above the concentration of 1000 mg kg⁻¹ the visible deposits were observed. The solution

containing 1000 mg kg⁻¹ AA produced the coatings which were not different in appearance from AA free coatings. Similarly, BHA and BHT were found to be suitable at a rate of 100 mg kg⁻¹.

Table 6 Regression coefficients and adjusted coefficients of determination (R^2) from prediction equations of PV, TBARS and sensory attributes with storage time in coated and uncoated peanuts^a

Dependent variable	Sample	Regression coefficient ^b			R ²
		A	b	c	
PV	CoBAPT	-0.1353±0.02932	0.0019±0.00022	2.2459±0.78868	0.9150
	CoBHT	-0.1979±0.04913	0.0027±0.00037	2.8511±1.32156	0.8813
	CoBHA	-0.1575±0.03282	0.0026±0.00025	2.4676±0.88279	0.9556
	CmBAPT	-0.1188±0.03276	0.0030±0.00025	2.1645±0.88142	0.9802
	CmBHA	-0.1021±0.04338	0.0039±0.00033	2.7006±1.16698	0.9834
	CmBHT	0.0001±0.04939	0.0036±0.00038	2.0167±1.32874	0.9834
	CoAA	-0.2717±0.06535	0.0072±0.00050	4.1657±1.75796	0.9864
	CmAA	0.1632±0.05209	0.0057±0.00040	2.3400±1.40126	0.9949
	Control	0.5584±0.18119	0.0066±0.00166	-0.6166±4.04513	0.9733
	TBRAS	CoBAPT	-0.0035±0.00320	0.0001±0.00002	0.1782±0.08598
CoBHT		-0.0038±0.01265	0.0002±0.00010	0.2425±0.34020	0.6938
CoBHA		-0.0148±0.01348	0.0005±0.00010	0.3191±0.36253	0.8821
CmBAPT		-0.0506±0.01320	0.0010±0.00010	0.5821±0.35503	0.9657
CmBHA		-0.0784±0.01886	0.0016±0.00014	0.8059±0.50738	0.9693
CmBHT		-0.1033±0.03935	0.0021±0.00030	0.8917±1.05857	0.9281
CoAA		-0.1660±0.03625	0.0028±0.00028	1.5414±0.97527	0.9686
CmAA		-0.2457±0.06798	0.0053±0.00052	2.2887±1.82882	0.9658
Control		0.0148±0.08637	0.0042±0.00066	-0.5477±2.32354	0.9658
Oxidized Flavor		CoBAPT	0.0231±0.03249	0.0001±0.00025	5.2910±0.87416
	CoBHT	-0.0348±0.03362	0.0006±0.00026	6.1746±0.90430	0.2817
	CoBHA	0.0110±0.03605	0.0004±0.00027	5.2804±0.96986	0.3682
	CmBAPT	-0.0820±0.03775	0.0015±0.00029	6.2354±1.01549	0.6929
	CmBHA	-0.2056±0.05157	0.0032±0.00039	7.7804±1.38735	0.8040
	CmBHT	-0.1737±0.04386	0.0034±0.00033	7.0979±1.17986	0.8958
	CoAA	-0.3250±0.05856	0.0056±0.00045	8.4206±1.57523	0.9206
	CmAA	-0.2003±0.08282	0.0075±0.00063	7.2698±2.22789	0.9497
	Control	-0.3588±0.08836	0.0113±0.00081	6.8016±1.97273	0.9614

^a Data is displayed as Means±Standard Error, *n*=3 PV and TBARS and *n*=9 for Oxidized flavor

^b Regression coefficients for the general regression equation: y=a*x+b*x²+c where y=dependent variable (PV,TBARS, and sensory attributes) and x=independent variable days of storage

CoBAPT Gum cordia+BHA/BHT, *CoBHT* Gum cordia+BHT, *CoBHA* Gum cordia+BHA, *CmBAPT* CMC+BHA/BHT, *CmBHT* CMC+BHT, *CmBHA* CMC+BHA, *CoAA* Gum cordia+ascorbic acid, *CmAA* CMC+ascorbic acid

^a Data is displayed as Means±Standard Error, $n=3$ PV and TBARS and $n=9$ for Oxidized flavor

^b Regression coefficients for the general regression equation: $y = a \cdot x + b \cdot x^2 + c$ where y =dependent variable (PV,TBARS, and sensory attributes) and x =independent variable days of storage

Fig. 1 Effects of different coatings on shelf life of peanuts. Data is displayed as Mean $\pm$ 95 % C.I. *CoBAPT* Gum cordia+BHA/BHT, *CoBHT* Gum cordia+BHT, *CoBHA* Gum cordia+BHA, *CmBAPT* CMC+BHA/BHT, *CmBHT* CMC+BHT, *CmBHA* CMC+BHA, *CoAA* Gum cordia+ascorbic acid, *CmAA* CMC+ascorbic acid

The coating effectiveness as evaluated by weight gain after coating is presented in Table 2. Due to adhesive nature, gum cordia was deposited significantly higher than CMC. Adhesion is an important property of polymer and is defined as tendency of surface molecules of different substances to cling one another, such as clinging of coating material to food surfaces (Anonymous 1992). Strong adhesion results in difficult to detach coating with uniform surface coverage (Peyron 1991). Better deposition of gum cordia resulted initially higher amount of antioxidants in samples treated with this gum (Table 2), ultimately resulting in better performance throughout the storage.

Chemical and sensory parameters of oxidation were found to be increased during storage (Tables 3, 4 and 5). However, significant differences were observed between coated and control samples. Peroxide value was found to be significantly low in coated samples compared to control even after 21 days of storage. The critical PV at which a sample become unacceptable varies according to type of oil involve and presence of other factors. Evranuz (1993) reported that the edible quality of roasted peanuts is lost when PV value is between 42 to 47 meq.O₂ kg⁻¹. If the limited is 40 meq.O₂ kg⁻¹, then according to prediction equations (Table 6), the order of effectiveness of treatment is CoBAPT>CoBHT>CoBHA>CmBAPT>CmMBHA>CmBHT>CoAA>CmAA (Fig. 1). A fourfold increase in shelf life was achieved in the most effective treatment CoBAPT compared to control.

Among the two synthetic antioxidants, BHT was found to be more effective than BHA when applied by gum cordia but when applied by CMC, BHA was found to be more effective than BHT. BHA and BHT are hindered phenols; BHT being more hindered than BHA. In several model systems, BHA has shown more effectiveness than BHT (Gulcin et al. 2004; Gadow et al. 1997). In case of real samples, in which antioxidants are applied by incorporating them into some carrier, the effectiveness also depends on release kinetics. Sharma et al. (1997) reported BHA to be least effective among BHA, BHT and tertiary butylhydroquinone (TBHQ) on snacks samples using salt as carrier. In contradiction, Lin et al. (2009) found BHA to be more effective than BHT on fish ball samples when applied by incorporating into zein coating. In our case it is proposed that gum cordia released BHT faster than BHA due to its higher lipophilic nature. Since CMC is not a good carrier of additives (Braudo et al. 1998; Galazka et al. 1996), therefore release of BHA or BHT was indifference hence BHA was found to be more effective. However further research on release kinetics is required. In combination, BHA and BHT were found more effective than alone. The interaction of BHA with peroxy radical resulted in BHA phenoxy radical who has the ability to abstract hydrogen from the hydroxyl group of BHT and regenerate BHA. This resulted in enhanced performance of BHA and BHT in combination (Reische et al. 1998).

Table 7 Correlation coefficients among the variables: PV, TBARS and oxidized flavor of peanuts^a

Related variables/Treatment	PV and TBARS	PV and Oxidized	TBARS and Oxidized
CoBAPT	0.748	0.201	0.217
CoBHT	0.253	0.232	0.134
CoBHA	0.797	0.420	0.451
CmBAPT	0.976	0.725	0.652
CmBHA	0.981	0.789	0.790
CmBHT	0.953	0.902	0.908
CoAA	0.981	0.967	0.977
CmAA	0.969	0.943	0.950
Control	0.923	0.952	0.952

^a *CoBAPT* Gum cordia+BHA/BHT, *CoBHT* Gum cordia+BHT, *CoBHA* Gum cordia+BHA, *CmBAPT* CMC+BHA/BHT, *CmBHT* CMC+BHT, *CmBHA* CMC+BHA, *CoAA* Gum cordia+ascorbic acid, *CmAA* CMC+ascorbic acid

Though the samples coated with AA increased the shelf life of peanuts but they exhibited significantly dark color during storage. The antioxidant activity of AA depends on pH; being more effective at high pH (Liao and Seib 1988). At pH 6–8, AA oxidizes to ascorbic radical and further to dehydroascorbic acid; both have radicals scavenging activity. However, at this pH these forms of AA are highly unstable and may initiate browning reactions (Ahmed and Young 1982).

Thiobarbituric acid reactive species (TBARS) were found to be increased throughout storage in control as well as coated samples. However, the first significant difference between control and coated samples were observed after 42 days. Thiobarbituric acid reacts with secondary oxidation product which are produced by the degradation of peroxide, thus required an amount of peroxides to be accumulated before increase (Kosugi et al. 1989).

Peroxide value and TBARS were found to be correlated well ($R > 0.8$) for all samples (Table 7). On the other hand, these parameters (PV and TBARS) exhibited variable correlation with sensory evaluation depending on the level of oxidation. Samples having high PV showed stronger correlation between sensory evaluation and chemical oxidation parameters compared to samples having low PV. This is in line with the previous findings regarding PV and sensory changes e.g. Mestrallet et al. (2009) and Nepote et al. (2006) observed good correlation between sensory and chemical oxidation of roasted peanuts at high PV (5–120 meq.O₂ kg⁻¹) while Baker et al. (2002) did not observe same correlation due to low PV (2–9 meq.O₂ kg⁻¹).

The regression equations of dependant variables (PV, TBARS and oxidized flavor) are presented in Table 6. The dependant variables showed $R^2 > 0.8$ except in case of oxidized flavor ratings of very low oxidized samples. These equations can be used to predict the effect of storage time on quality attributes in peanuts. In case of PV, the sign of linear and quadratic terms was found to be varied from sample to sample, indicating a possible change in mechanism of oxidation. Whereas, in case of TBARS and oxidized flavor rating, a negative linear and positive quadratic term was obtained, this is an indication of induction period.

Conclusion

The results of this work indicate that gum cordia is a good carrier of antioxidants and can potentially be used to deliver other functional food ingredients using edible coatings. Further work is underdevelopment to determine its effectiveness under different conditions.

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