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Research Article

Quality of bread with added turmeric (*Curcuma longa)*: powder, essential oil and extracted residues

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Abstract

This research aimed to develop healthier bread by adding turmeric (*Curcuma longa*); whole turmeric powder (TP), turmeric essential oil (TEO) and turmeric residue (TR) from the essential oil extraction. Randomized completed block design (RCBD) was used for four different portion, 0.10-0.30% base on flour weight of turmeric adding were evaluated by 9-scale hedonic sensory evaluation. The 0.10% turmeric adding TP, TEO and TR were the most liked with the moderate score (6.08-6.90 overall liking score) from 25 panelists. The 0.10% TP added bread had 0.0012% curcuminoid, 25.08 mg gallic acid total phenolic content, 9.18 mg vitamin C/100 g for DPPH radical scavenging activity and 29.3% moisture content. The compression force (hardness), L*, a* and b* were 23.08 N, 81.30, -1.56 and 40.67 respectively. The optimized formulae were calculated by Response Surface Method (RSM). The developed process was 185^{o}C and 15 minutes baking. The compression force, L*, a*, b* and moisture content of 0.10% TEO added bread were 24.14 N, 79.89, -1.39, 44.65 and 27.31% respectively, but the curcuminoid was not detected. For 0.10% TR added bread, it had 24.46 N compression force. The antioxidant activity of 0.014% curcuminoid was 5448.69 mg vitamin C/100g dry weight bread and its moisture was 28.52%. The sensory attributes of three treatments, 0.10% TP, 0.10% TEO and 0.10% TR adding were evaluated. The results showed

that 0.10% TR added bread had the highest score (6.87 overall liking score) but they had no significant difference ($p>0.05$). It contained moisture, carbohydrate, protein, fat, fibre and ash at 28.52%, 56.91%, 10.53%, 1.79%, 0.47%, and 1.74%, respectively, Moreover, the addition of TR can extend the shelf life of bread for 4 days at room temperature and 5 days at 25^{o}C.

Keywords: food additives, turmeric powder, essential oil, residue, bread, Thailand.

Introduction

Turmeric *(Curcuma longa)* is a plant in *Zingiberaceae* family which commonly found in East Asia. It is cultivated primarily in Bengal, China, Taiwan, Sri Lanka, Java, Peru, Australia and the West India. It is an ancient spice which used as dye and a condiment from antiquity. The turmeric powder is commonly used as spice in South Asian cuisines. The rhizomes or roots of turmeric are boiled or steamed, then dried and ground in deep orange-yellow powder. The active substance in turmeric is curcuminiod which presents yellow color and antioxidant properties. Turmeric has earthy, peppery and bitter flavor and also has a mustard smell. Turmeric is a mild digestive, a stimulant a carminative. (Grieve, 1992 and Srimal, 1997) It has an ointment, antiinflamation, antiseptic, antibacterial, anti-fungi properties and also being aromatic. Curcumin has been shown to be active against *Staphylococcus aurous* (pus-producing infections) (Too ji Hoong, 2008). Turmeric water is an Asian cosmetic applied to impart a golden glow to the complexion.

Bread is a staple food prepared by baking dough of flour and water. It may be leavened or unleavened. Salt, fat and leavening agents such as yeast and baking soda are common ingredients, though bread may contain a range of other ingredients: milk, egg, sugar, spice, fruit (such as raisins), vegetables (such as onion), nuts (such as walnuts) or seeds (such as poppy seeds). Bread is one of the oldest prepared foods, dating back to the Neolithic era. The development of leavened bread can probably also be traced to prehistoric times.

Fresh bread is prized for its taste, aroma, quality and texture. Retaining its freshness is important to keep it appetizing. Bread that has stiffened or dried past its prime is said to be stale. Modern bread is sometimes wrapped in paper or plastic film, or stored in a container such as a breadbox to keep it fresh longer. Bread that is kept in warm, moist environments is prone to the growth of mold. Bread kept at low temperatures, for example, in a refrigerator, will develop mold growth more slowly than bread kept at room temperature. However, unwrapped bread kept in a typical household refrigerator will turn stale quickly due to the low humidity of the air (Peter, 2001).

Bread is bakery product by foreigner ate meal. There is the research of effect on the bread shelf life from cinnamon and clove essential oils adding (Sirinard, 2005). The bread that contained 0.25 and 0.50 essential oils from cinnamon and clove (by weight of flour) showed that the essential oils coursed complete inhibition of mold growth for 7 days at room temperature (28^{o}C) but It was not acceptable in sensory characteristics, especially in odor of essential oils. The bread that added cinnamon essential oil had higher firmness and hardness than the control (0%) but the clove essential oil had no significant difference on texture of bread. The bread was acceptable in sensory characteristics, especially in odor of essential oils. When the essential oils were reduced to the level 0.10% (by weight of flour).This product was kept at room temperature for 3 days without mold growth. Moreover, the using of 5% *Glycyorrrhiza uralensis* and *Curcuma longa* in bread as improve the higher antioxidant property and did not change the moisture content of bread. (So-young *et al*., 2006).

This research aimed to develop the healthy bread by adding turmeric (*Curcuma longa*); whole turmeric powder (TP), turmeric essential oil (TEO) and turmeric residue (TR) from the essential oil extraction. The optimum concentrations of TP, TEO and TR adding were considered which based on the evaluation of consumer acceptability, sensory evaluation, physical property, chemical property, microbiological property The final product also was determined the shelf life.

Materials and Methods

Preparation of raw materials

Turmeric powder (TP): Fresh Ratchaburi turmeric was cleaned, peeled and sliced to thin pieces then were dried in 70^{o}C hot air oven for 6-7 hours. The dried turmeric was blended by blender and mashed with 0.75 mesh Ultra Centrifugal mill and stored in the plastic bag at chill temperature.

Turmeric essential oil (TEO): The 200 g turmeric powder was extracted with steam distillation in 2 L round flask and boiled for 3 hours. The turmeric essential oil was kept in dark bottle until used.

Turmeric residue (TR): The residue of turmeric essential oil extraction was dried in hot air oven until dry (moisture content ≤ 10%) and stored the plastic bag at chill temperature.

All turmeric samples were evaluated on colour, moisture content, curcuminoid (ASTA, 1985), antioxidant activity with DPPH Radical scavenging activity (Kim *et al.*, 2002) and total phenolic content (Singleton and Rossi, 1965).

Preparation of turmeric bread

Randomized completed block design (RCBD) was used for experimental design. The turmeric powder (TP) samples were applied in bread with 5 levels; 0, 0.10, 0.15, 0.20 and 0.25% (based on flour weight). The turmeric essential oil (TEO) was added in the bread with 4 levels; 0, 0.10, 0.20 and 0.30%. The turmeric residue was added for 5 levels; 0, 0.10, 0.15, 0.20 and 0.25%. The original formulae of bread composed of flour, sugar, water, bread improver, milk powder (low butter), shortening, salt, yeast with 56, 2.8, 34.6, 0.3, 2.2, 2.8, 0.6 and 0.7 respectively. The turmeric samples were added to bread during dough making. However, the bread dough was done by quick method which flour, yeast and milk powder were mixed together with low speed spinning. Sugar and salt were dissolved in water then slowly poured into the mixed flour with medium speed spinning for 12 minutes. After 20 minute fermentation of dough, it was kneaded to punch the air and divided into 140 g loaves then continued with the 15 minute fermentation. The dough was spreaded to rectangle and rolled then put the dough in 4 x 10 x 3 inch mold with white butter coating. The dough was proofed in mold for 1 hour then baked at 185^{o}C for 15 minutes and let bread cooled to room temperature. The bread was evaluated the physical, chemical, microbiological properties and sensory evaluation.

The 2 x 2 factorial designs with temperature and baking time were varied to 185, 190^{o} C and 10, 15 min. for evaluation of optimized formulae. The most liking formulae were testing by the panelist then calculated with RSM. (Response Surface Method).

The experimental results were analyzed by ANOVA and mean procedure of SAS (Statistical Analysis System) (SAS, 1996). Duncan's Multiple Range Test was used to detect mean differences.

Evaluation of physical, chemical, microbiological and sensory properties

Physical properties
Colorimetric measurements: the color of TP, TEO and TR samples were determined at three random locations on the crumb of each sample with spectrophotometer (Spectra flash 600 plus, Data Color International, USA).

The CIE color values were recorded as L* = lightness (0 = black, 100 = white), a* (-a*= greenness, +a* = redness), b* (-b* = blueness, +b* = yellowness). Source: Illuminants A, D 65 10 Deg.

Water activity (a_w) was analyzed by AOAC method (2000).

Texture measurement: The compression (hardness) of bread samples were measured by a Texture Analyzer model TA – XT_{2i} (Stable Micro System Ltd., Surrey, England) with P/100 mm diameter aluminum platen, pretest speed 1 mm/s, test speed 1.7 mm/s, post speed 10 mm/s and strain 40%. The bread was tested individually and the result of each sample was from the average of ten measurements.

Chemical properties

- Total curcuminoid content by ASTA Method (1985).
- Antioxidant by DPPH Radical scavenging activity (Kim *et al*., 2002).
- Total phenolic content by Singleton and Rossi. (1965).
- Proximate test: moisture, protein, fat, crude fiber and ash content according to AOAC (2000), and carbohydrate content was from calculation.

Microbiological properties
Total plate count (TPC) and Yeast & Mold (Y&M) by BAM Method 1998.

Sensory evaluation
The sensory attributes of baked samples were evaluated by 25 semi-trained panelists (Under with trained descriptive panelists) with the randomized completed block design. A 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) was used to evaluate the acceptability of product attributes (appearance, color, flavor, texture and overall like). For consumer acceptance of bread with turmeric residue, the samples were evaluated by 197 untrained panelists. The panelists were asked to evaluate the acceptability of the best sample from the experiments.

Study of shelf life

The samples were packed in a Nylon bag with oxygen absorbers 100cc then stored at 25^{o}C and room temperature for 7 days. The shelf life of TR bread was compared with control breads (no addition of turmeric) in the storage. The water activity (A_w) , color value, moisture content, compression force (texture) , TPC and Y&M were evaluated.

Results and Discussion

Properties of raw materials

Physical and chemical composition of turmeric samples are shown in Table 1. The turmeric powder had more orange yellowness than turmeric essential oil and turmeric residue. For moisture content, the turmeric residue was lower than turmeric powder. Total curcuminoid content of turmeric powder was higher than turmeric residue and turmeric essential oil which was 9.98% (w/w). Turmeric essential oil had essential oil crude 8.33 % (v/w) but did not contain total phenolic. Antioxidant activity of turmeric residue was higher than turmeric powder and turmeric essential oil.

Table 1. Physical and chemical properties of turmeric powder, turmeric essential oil and turmeric residue.

Components	**Turmeric powder** Mean ± SD	**Turmeric essential oil** Mean ± SD	**Turmeric residue** Mean ± SD
Colour L*	60.95 ± 0.70	95.64 ± 0.03	58.56 ±0.28
a*	23.40 ± 0.46	-8.07 ± 0.01	19.92 ±0.15
b*	41.79 ± 0.43	22.11 ± 0.01	35.34 ±0.74
Moisture (%)	8.09 ± 0.40	-	4.91 ±0.71
Total curcuminoids (% w/w)	9.98 ± 0.14	0.007 ± 0.00	9.02 ±0.21
Antioxidant activity (mg.vit. C equl /100g sample)	5067.12 ± 0.00	23.86 ± 0.24	5448.69 ±77.13
Total phenolic (mg. gallic acid equal /100g sample)	5965.82± 531.17	-	4714.39±511.41
Essential Oil crude (%) (V/W)	-	8.33 ± 0.15	-

SD = standard deviation - = no analysis

Physical chemical and sensory properties of TP, TEO and TR added bread

The result of physical and chemical analysis of turmeric powder adding bread showed 0.25% TP in bread had moisture content 31.71%, dark yellow color and 0.27% total curcuminoid content which was highest amount. But its compression force (hardness) was lower than include 12.02 Newton. All samples were significant different ($P<0.05$). For sensory evaluation of turmeric powder adding bread found like 0.10% TP added bread in overall of appearance color flavor texture include 6.45 compare control were not significant different ($P>0.05$) because it presented slightly turmeric flavor. The 0.10% turmeric powder adding bread were highter moisture content, light yellow color which were significant different with control sample. But the compression force was lower than all samples. For the curcuminoid content, it did not present in any samples. The sensory evaluated score of 0.10% TEO adding bread was 6.08 which were significant different with control ($P<0.05$). So 0.10% adding was the optimum level because the consumer did not accept the high amount adding of TEO. The results of physical and chemical properties of 0.10-0.25% turmeric residue adding bread showed 28.95-30.03% moisture content which were significant different with control ($p<0.05$). The 0.10% TR had lighter yellow color than turmeric powder adding bread. For texture, its compression force had higher than control and 0.15-0.25% TR adding significantly ($P<0.05$). The results of sensory evaluation showed that 0.10% TR adding was the optimum level. Because it had 6.90 overall liking score which was not significant different with control in Table 2.

Table 2. Physical, chemical and sensory properties of TP, TEO, TR added bread.

Sample	Level (%)	Moisture (%) Mean±SD.	Colour Mean±SD.			Total Curcuminnoid (%)	Compression Force (Newton) Mean±SD.	Sensory of overall (Score) Mean±SD.
			L*	a*	b*			
Turmeric powder	0	27.60 ^{b} ± 3.40	77.17 ^{b} ± 0.01	-0.2 ^{a} ± 0.09	10.82 ^{e} ± 0.13	0.000 ^{e}	21.33 ^{a} ± 4.78	6.45 ^{a} ± 1.10
	0.10	29.30 ^{ab} ± 0.48	80.15 ^{a} ± 1.58	-5.71 ^{d} ± 0.24	43.12 ^{d} ± 1.23	0.009 ^{d}	18.27 ^{b} ± 2.48	6.45 ^{a} ± 1.28
	0.15	28.55 ^{ab} ± 1.47	76.11 ^{b} ± 1.18	-4.46 ^{c} ± 0.48	46.37 ^{c} ± 0.41	0.015 ^{c}	18.12 ^{b} ± 1.58	6.05 ^{ab} ± 1.05
	0.20	28.92 ^{ab} ± 1.14	77.26 ^{b} ± 0.53	-4.90 ^{c} ± 0.17	49.73 ^{b} ± 0.32	0.023 ^{b}	15.22 ^{c} ± 2.75	5.75 ^{b} ± 1.37
	0.25	31.71 ^{a} ± 0.40	78.23 ^{ab} ± 2.23	-3.57 ^{b} ± 0.39	53.09 ^{a} ± 1.91	0.027 ^{a}	12.02 ^{d} ± 1.57	5.55 ^{b} ± 1.54
Turmeric essential oil	0	29.57 ^{d} ± 0.20	81.08 ^{b} ± 0.24	3.68 ^{a} ± 0.11	16.88 ^{a} ± 0.30	0	36.31 ^{a} ± 2.44	7.25 ^{a} ± 0.97
	0.10	31.17 ^{b} ± 0.11	82.91 ^{a} ± 0.32	2.54 ^{b} ± 0.15	15.96 ^{a} ± 0.26	0	29.71 ^{b} ± 1.94	6.08 ^{b} ± 1.64
	0.20	31.55 ^{a} ± 0.11	82.65 ^{a} ± 0.47	2.59 ^{b} ± 0.47	16.45 ^{a} ± 0.86	0	32.53 ^{b} ± 4.38	5.75 ^{b} ± 1.77
	0.30	30.36 ^{c} ± 0.16	82.18 ^{a} ± 0.51	3.05 ^{b} ± 0.36	16.68 ^{a} ± 0.41	0	31.12 ^{b} ± 3.67	4.80 ^{c} ± 1.79
Turmeric residue	0	25.46 ^{b} ± 1.73	81.70 ^{a} ± 0.05	2.70 ^{a} ± 0.17	17.36 ^{d} ± 0.63	0.00 ^{d}	22.14 ^{b} ± 2.02	7.02 ^{a} ± 1.03
	0.10	29.77 ^{a} ± 0.24	81.30 ^{ab} ± 0.24	-1.86 ^{b} ± 0.29	40.67 ^{c} ± 0.10	0.013 ^{c}	25.67 ^{a} ± 1.81	6.90 ^{ab} ± 1.15
	0.15	30.03 ^{a} ± 1.35	79.89 ^{bc} ± 0.69	-1.39 ^{b} ± 0.67	44.65 ^{b} ± 0.25	0.018 ^{b}	21.41 ^{b} ± 1.75	6.43 ^{bc} ± 1.16
	0.20	28.95 ^{a} ± 0.42	79.28 ^{c} ± 1.13	-0.94 ^{b} ± 0.40	46.29 ^{b} ± 1.42	0.021 ^{b}	22.26 ^{b} ± 2.41	6.48 ^{bc} ± 1.33
	0.25	29.93 ^{a} ± 0.09	79.29 ^{c} ±1.57	-0.64 ^{b} ± 1.53	48.88 ^{a} ± 1.40	0.027 ^{a}	24.87 ^{a} ± 1.37	5.98 ^{c} ± 1.06

^{a,b,c}*Mean in a column on the sample with a different level are significantly different ($p< 0.05$)*

Model of response surface method

From 2 x 2 factorial design and Response Surface Method, the results showed in Table 3 the moisture content, compression force (texture) , color L* and b* had strongly effect to TP adding bread wherewith P-value of lack to fit had significant different (P>0.05). The optimum baking temperature and time were 185^{o}C and 15 minutes.

Table 3. Regression coefficient (R^2) and regression equation for temperature and time of bread with turmeric powder.

Factor (P)	R^2 (%)	Regression equation	LOF
Compression Force (N)	84.7	$Y = 107.434 - 0.568x_1 + 1.936x_2$	0.098
Colour L*	77.0	$Y = 102.622 - 0.085x_1 - 0.487 x_2$	0.211
b*	75.7	$Y = 9.692 + 0.238x_1 - 0.61x_2$	0.472

x_1: temperature x_2 : time LOF = Lack of fit

Proximate evaluation of bread added with turmeric powder or turmeric essential oil or extract residue at 0.10%

The moisture content of control (25.77%) was lower than TP, TEO and TR bread significantly (P<0.05). Ash, protein, fat of control was lower than TP, TEO and TR bread significantly and the same of crude fiber. The carbohydrate content of control was higher than all samples significantly in the Table 4.

Table 4. Proximate evaluation of bread added with turmeric powder or turmeric essential oil or turmeric residue at 0.10%.

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Crude Fibre (%)	CHO (%)
Control	25.77 ^{b}	1.55 ^{c}	8.83 ^{b}	1.74 ^{c}	0.47 ^{b}	61.64 ^{a}
TP	28.71 ^{a}	1.66 ^{b}	9.17 ^{ab}	1.82 ^{ab}	0.43 ^{c}	58.21 ^{b}
TEO	30.31 ^{ab}	1.74 ^{a}	10.4 ^{a}	1.87 ^{a}	0.53 ^{a}	58.15 ^{b}
TR	28.52 ^{a}	1.74 ^{a}	10.53 ^{a}	1.79 ^{bc}	0.47 ^{b}	56.95 ^{b}

^{a,b,c}*Mean in a column with a different superscript letter are significantly different (p< 0.05)*

Chemical and microbiological properties in bread added with turmeric powder, turmeric essential oil and turmeric residue

The results are shown in Table 5. The antioxidant activity and total phenolic of TR were higher than all samples 10.72 mg vitamin C/100 gram and 31.59 mg gallic acid per 100 gram. There was no microbiology detection in all samples.

Table 5. Quality of chemical and microbiological in bread added turmeric powder, turmeric essential oil and turmeric residue at 0.10%

Samples	Antioxidant activity	Total Phenolic	Total plate count	Yeast and Mould
	Mg/100 g	Mg/100 g	CFU/g	CFU/g
Control	7.14 ^{c}	23.88 ^{b}	N.D.	N.D.
TP	9.18 ^{b}	25.08 ^{c}	N.D.	N.D.
TEO	7.19 ^{c}	24.22 ^{c}	N.D.	N.D.
TR	10.72 ^{a}	31.59 ^{b}	N.D.	N.D.

^{a,b,c}*Mean in a column with a different superscript letter are significantly different (p< 0.05)* N.D. = not detecte

Table 5. Quality of chemical and microbiological in bread added turmeric powder, turmeric essential oil and turmeric residue at 0.10%

Samples	Antioxidant activity	Total Phenolic	Total plate count	Yeast and Mould
	Mg/100 g	Mg/100 g	CFU/g	CFU/g
Control	7.14 [c]	23.88 [b]	N.D.	N.D.
TP	9.18 [b]	25.08 [c]	N.D.	N.D.
TEO	7.19 [c]	24.22 [c]	N.D.	N.D.
TR	10.72 [a]	31.59 [b]	N.D.	N.D.

[a,b,c]*Mean in a column with a different superscript letter are significantly different (p< 0.05)*

N.D. = not detected

Sensory evaluation

The result sensory evaluation of TP, TEO and TR adding bread shown that panelist accept appearance of bread added TR because had light yellow color, light odour of turmeric residue and good taste significantly (P<0.05). Texture and overall of bread added TR had higher liking score which not significant different all sample. So the select bread with TR was the optimum to consumer test shown Table 6.

Table 6. Quality of sensory evaluation in bread added TP, TEO and TR at 0.10%.

Sample	Characteristics ± SD					
	Appearance	Colour	Odour	Taste	Texture	Overall like
TP	7.25 [a] ± 0.85	6.95 [a] ± 1.15	6.10 [b] ± 1.12	6.60 [a] ± 0.88	7.05 [a] ± 1.05	6.63 [ab] ± 0.99
TEO	7.45 [a] ± 1.10	7.00 [a] ± 1.34	6.05 [b] ± 1.28	5.95 [b] ± 1.23	7.00 [a] ± 0.65	6.05 [b] ± 1.10
TR	7.25 [a] ± 0.72	7.30 [a] ± 0.73	6.85 [a] ± 0.75	6.75 [a] ± 1.02	7.05 [a] ± 1.05	6.87 [a] ± 0.92

[a,b,c]*Mean in a column with a different superscript letter are significantly different (p< 0.05)*

For the consumer test, 197 consumers had both Thai and foreigner which had 63.5% female and 34% man. There was 37.1% in the age of 19-25 years and 28.4% for the age of 26-35 years which were 36% student, 27.9% government, 14% business, 12% private and 10.1% other. They were 45.7% education of Bachelor's degree and 24.9% Master's degree. The sensory evaluation showed the medium acceptance for all aspects. Thai consumers showed medium acceptance (score=7) with appearance, color, flavor, texture and overall which included 46.7, 37.5, 33.7, 35.9 and 46.7 percent respectively. The foreigners came from China, Ireland, Sweden, Australia and France the results showed the medium to low (score = 6-7) with appearance, color, flavor, texture and overall which included 21.4, 35.7, 35.7, 35.7 and 42.9 percentage because they did not prefer turmeric flavor. Overall results, the consumer accepted the product.

Shelf life evaluation

The turmeric bread samples were packed in Nylon bag with the absorber at room temperature and 25^{o}C for 7 days. There was no significant effect of turmeric adding on moisture content and water activity when compared with control samples. For the color of samples; a*, b* were changed during storage with significant effect (p<0.05) while L* was not significant different. Texture of turmeric

bread significant differenced from control. All results were shown in Table 7, 8 and presented that than turmeric residue adding bread can be stored for 4 days at room temperature 5 days at 25^{o}C follow standard community of bread had total plate count no more 1 x 10^{4} colony/sample. Selection yeast and mold must no more 100 colony/sample. Due turmeric have anti-fungi property in the bread.

Table 7. Comparison of bread with control and turmeric residue in nylon bags to storage 7 day at room temperature.

Package	Quality	Sample	Storage time (days)						
			0	1	2	3	4	5	6
Nylon bag with oxygen absorber 100 CC	Aw	Control	0.89 ± 0.02 a	0.892 ± 0.02 a	0.910 ± 0.04 a	0.885 ± 0.02 a	0.887 ± 0.01 a	0.888 ± 0.02 a	0.891 ± 0.01 a
		TR	0.90 ± 0.03 a	0.905 ± 0.04 a	0.908 ± 0.04 a	0.908 ± 0.03 a	0.909 ± 0.01 a	0.907 ± 0.02 a	0.918 ± 0.02 a
		T-test	NS	NS	NS	NS	NS	NS	NS
	Moisture	Control	25.77 ± 1.55 h	30.60 ± 0.43 cde	30.09 ±0.15 de	30.62 ± 0.13 cde	32.33 ± .33 ab	30.90 ± .05 cde	31.94 ± 0.71 bc
		TR	28.52 ± 0.42 fg	27.77 ± 0.19 g	29.55 ± .08 ef	31.07 ± .24 bcd	32.35 ±0.13 ab	30.87 ±0.09 cde	33.57 ±0.03 a
		T-test	NS	NS	NS	NS	NS	NS	NS
	Colour L*	Control	81.7 ± 0.05 abc	82.76 ±0.28 ab	80.12 ± 0.52 bcd	81.82 ± .20 abc	79.34 ± 1.21 bcd	80.64 ± 0.84 bcd	84.86 ± 6.27 a
		TR	79.27 ± 1.13 bcd	78.63 ± 0.87 cd	79.39 ± 0.24 bcd	81.44 ± 0.92 abcd	77.98 ± 0.79 d	80.89 ± 0.86 bcd	80.07 ± 1.70 bcd
		T-test	NS	NS	NS	NS	NS	NS	NS
	a*	Control	2.70 ± 0.17 b	2.51 ± 0.31 b	4.12 ± 0.48 a	2.62 ± 0.44 b	2.76 ± 0.70 b	2.67 ± 0.15 b	2.65 ± 0.15 b
		TR	-0.94 ± 0.40 de	0.42 ± 0.57 c	-0.09 ± 0.74 cd	-2.14 ± 1.15 f	-0.13 ± 0.39 cd	-1.88 ± 0.44 ef	-1.30 ± 0.74 ef
		T-test	**	**	**	**	**	**	**
	b*	Control	17.36 ± 0.63 fg	17.17 ± 0.77 fg	18.10 ± 0.45 f	15.23 ± 0.20 h	16.99 ± 1.03 fg	16.55 ± 0.48 g	16.50 ± 0.13 g
		TR	46.29 ± 1.42 a	37.51 ± 0.97 bcd	36.17 ± 0.29 e	38.16 ± 0.15 bc	36.74 ± 0.96 de	38.69 ± 0.45 b	36.94 ± 0.58 cde
		T-test	**	**	**	**	**	**	**
	Compression Force (N)	Control	22.30 ± 4.78 de	24.51 ± 3.57 de	25.21 ± 1.52 d	31.04 ± 3.57 c	35.88 ± 2.01 b	40.44 ± 4.00 a	39.99 ± 3.82 a
		TR	23.78 ± 1.15 de	28.61 ± 1.88 c	28.62 ± 1.80 c	31.38 ± 3.25 c	38.66 ± 4.32 ab	39.99 ± 2.38 a	39.27 ± 5.86 b
		T-test	**	**	**	NS	NS	NS	NS
	Total Plate Count (CFU/g)	Control	N.D.	N.D.	1.75×10^2	1.11×10^2	3.45×10^2	5.62×10^2	2.5×10^3
		TR	N.D.	N.D.	N.D.	2.14×10^2	5.62×10^2	6.11×10^2	3.5×10^3
	Yeast and Mold (CFU/g)	Control	N.D.	N.D.	N.D.	70	1×10^2	5.25×10^2	5.3×10^2
		TR	N.D.	N.D.	N.D.	50	75	3.5×10^2	4×10^2

Remark: Values in the same row followed by different letters are significantly different at P< 0.05

** = significant different at P< 0.05

NS = non-significant N.D.= not detected

Table 8. Comparison of bread with control and turmeric residue in nylon bags to storage 7 days at 25°C.

Package	Quality	Sample	Storage time at 25°C (days)			
			0	2	4	6
Nylon bag with oxygen absorber 100 CC	Aw	Control	0.89 ± 0.01 a	0.892 ± 0.01 a	0.921 ± 0.01 a	0.897 ± 0.01 a
		TR	0.90 ± 0.03 a	0.909 ± 0.02 a	0.921 ± 0.02 a	0.913 ± 0.02 a
		T-test	NS	NS	NS	NS
	Moisture (%)	Control	25.77 ± 1.55 c	33.66 ± 0.432 a	33.58 ± .101 a	33.76 ± 0.031 a
		TR	28.52 ± 0.42 b	33.81 ± 0.252 a	34.13 ± 0.081a	33.68 ± 0.137 a
		T-test	NS	NS	NS	NS
	Color L*	Control	81.70 ± 0.05 b	83.37 ± 0.31 a	81.19 ± 0.61 b	82.18 ± 0.15 b
		TR	79.32 ± 1.13 c	81.53 ± .22 b	81.63 ± 0.85 b	81.51 ± 0.28 e
		T-test	NS	NS	NS	NS
	a*	Control	2.70 ± 0.17 a	1.69 ± 0.39 b	2.26 ± 0.14 a	2.35 ± 0.05 a
		TR	-0.94 ± 0.40 c	-2.99 ± 0.39 d	-3.92 ± 0.16 e	-2.57 ± 0.21 d
		T-test	*	*	*	*
	b*	Control	17.36 ± 0.63 c	15.44 ± 0.35 d	17.26 ± 1.27 c	16.21 ± 0.62 cd
		TR	46.29 ± 1.42 a	41.33 ± 0.73 b	41.91 ± 0.93 b	40.75 ± 0.31 b
		T-test	*	*	*	*
	Compression Force (N)	Control	22.30 ± 4.78 c	30.76 ± 3.55 b	39.36 ± 5.34 a	39.38 ± 5.86 a
		TR	23.78 ± 1.15 c	29.57 ± 2.10 b	32.794 ± 3.12 b	41.13 ± 3.18 a
		T-test	*	NS	*	NS
	Total Plate Count (CFU/g)	Control	N.D.	60	5.50×10^2	3.25×10^3
		TR	N.D	N.D	5.62×10^2	1.5×10^3
	Yeast and Mold (CFU/g)	Control	N.D	N.D	80	2×10^2
		TR	N.D	N.D	50	1.6×10^2

Remark: Values in the same row followed by different letters are significantly different at P< 0.05

* = significant different at P< 0.05

NS = non-significant N.D.= not detected

Conclusion

There is 1.05% of curcuminoid in Ratchaburi fresh Turmeric. When it was processed to turmeric powder, turmeric essential oil and turmeric residue, the results showed total curcuminoid antioxidant activity and total phenolic in TP and TR are higher than TEO. The same result, the total curcuminoid of TP and TR in added bread are higher than TEO. The result of sensory evaluation panelist acceptance with appearance, colour, odour, taste, texture and overall of bread added TR more than TP and TEO. The acceptance of consumer is the same as the panelist. For shelf life of bread added TR in nylon bag with absorber at room temperature and 25°C compared with control showed that it can be kept for 4 days at room temperature and 5 days at 25°C with significant different (P<0.05).

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