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The effect of atmospheric cold plasma (ACP) treatment on colour, water activity, antioxidant activity and total phenolic content of mango flour noodles during storage

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Abstract

This work aimed to evaluate the effect of Atmospheric Cold Plasma (ACP) on the quality of mango flour noodles (NMF). ACP treatment of 5 minutes duration on the surface of the noodles strands were performed and evaluated during three days of storage by monitoring parameters related to colour, water activity, antioxidant activity and total phenolic content. The lightness value *(L^*)* was higher for untreated samples (NMF (U)) than for treated samples (NMF (T)), while a greater increased in the redness *(a^*)* and yellowness *(b^*)* values were observed for the NMF (T). The changes in aw, antioxidant activity and total phenolic content (TPC) were negligible. However the NMF (T) showed significant different ($p<0.05$) in TPC between day 0 and 3 of storage day. Therefore ACP treatment preserved the antioxidant activity and TPC in the noodles. The use of ACP treatment has been proven satisfactory to treat mango flour noodles.

Introduction

Noodle, a traditional staple food in many Asian countries, has been consumed for thousands of years. It is becoming increasingly popular worldwide for its convenience, nutritional quality, and palatability (Li *et al*., 2012). For quite a long time, people could only buy dry noodles or instant fried noodles in supermarkets for ease of preservation. Even so, as a food product with a long history in China, nowadays, fresh noodle is attracting more and more people for its unique flavor and taste (Cai, 1998; Hou, 2001). According to FAMA (2007), noodles production in Malaysia was 96,600 tonnes with an annual growth rate of 3.5% for the year of 2007. Based on the current market price of noodles RM 3.00/kg, the total market sales for noodles are estimated to be RM 290 million per year.

Recently, the food industry endeavour to produce products that incorporated added value component, for instance dietary fibre or more recently, phytochemicals for examples antioxidants and polyphenols. Fruits' by-products can comprise a high dietary value and possibly therefore considered as the functional food ingredients (Ramirez *et al.*, 2015). In such a case, foods substituted with edible fruit by-products are likely to be a new food ingredient type that can create demand by prospect production. Mango flour fresh noodle is an added value product that contains mango peels and pulp flour substituted into noodles formulation. Mango flour noodles contained phenolic and provide high antioxidant attributed from mango substitution.

Non-thermal technologies have been reported as suitable options to treat food with high nutritional content (Misra *et al.*, 2015). Preservation of foods by non-thermal technologies atmospheric cold plasma (ACP) is an attractive alternative technique because it tends to infer minimal effects on the food quality and taste. ACP is an ionised gas characterised by active particles such as electrons, ions, free radicals and atoms that is produced by applying energy to a gas or a gas mixture. Operative and configuration conditions of the atmospheric plasma generators and the assessment of the efficacy of the ionised gas on microbial inactivation were extensively reviewed (Moreau *et al*., 2008). There is only a study on the effect of cold plasma on antioxidants activity of kiwi fruit (Ramazzina *et al.*, 2015). Moreover, there is a lack of data concerning the effect of cold plasma after storage of various types of foods. During storage, antioxidants and phenolics are prone to oxidation resulting to nutritional or sensory deterioration (Manzocco *et al.*, 2000). At present, the

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most common method to maintain the freshness of these products is trough the used of various chemical preservatives, such as potassium sorbate, sodium dehydroacetate and calcium propionate. However, it was highlighted that nowadays consumers are increasingly concerned about the safety of current food additives and becoming interested in natural ''green'' food (Serrano *et al.*, 2005).

It is important to evaluate the effect of atmospheric cold plasma (ACP) on water activity, colour, antioxidant activity and total phenolic content of mango flour noodles immediately after treatment and during storage. By using the novel local indigenous technique of ACP as a food preservation technique, the research can contribute in the course of preserving the crucial nutritional and functional compound in added value noodles for Malaysia's noodles industry instead of using harmful chemical.

For all these reasons, it is important to investigate the effect of ACP techniques on the scope focusing to colour, water activity, antioxidant activity and total phenolic content of fresh prepared mango flour noodles and assess the stability of the mango flour noodles after 3 days of storage.

Materials and Methods

Materials

Commercial noodle flour was obtained locally from the Yumi Food Sdn. Bhd, Malaysia. Mango (*Mangifera indica* cv. Perlis sunshine) was obtained from the local market in Perlis.

*Mango flour (*Mangifera indica *cv. Perlis sunshine) preparation*

The sliced mangoes were dried at 60°C for 48 hours, using a hot-air dryer (Binder). The dried mangoes were then ground and sieved into flour using a laboratory scale mill.

Noodle preparation

The flour mixtures, consists of wheat and mango flour ratios of 97:3 w/w, were blended in a noodles mixer (Automatic noodles and pasta machine) with salt solution until it achieved the final optimum water absorption for 10 min. The mixture was then extruded into noodles strands. The noodles were pre-cooked in boiling water for 1 min and rinsed with cool water. Noodles from mango flour (NMF (T)) treated with ACP were compared to mango flour noodles untreated with ACP served as control noodles (NMF (U)).

ACP treatment of mango flour noodles

ACP was setup as shown in Figure 1 with two

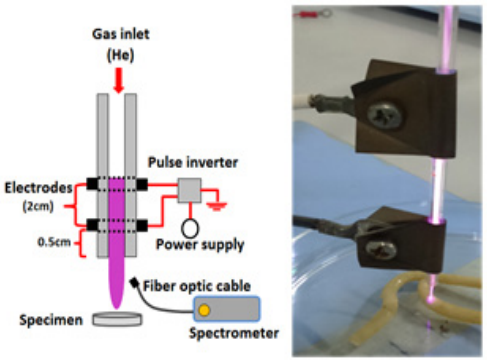

Figure 1. Plasma jet device and plasma when exposed to sample

copper electrode wrapped around the quartz glass tube that has the outer diameter of 2.0 mm and inner diameter of 1.5 mm. The distance between these two electrodes was 2 cm and the distance plasma source from the end of the quartz glass tube to the target sample was 5 cm.

Sample of noodles were exposed to the ACP for 5 min after cooking. Helium gas with flow rate of 1000 ml/min was used as a main gas source. The gas flow rate was controlled by the gas system controllers developed in Centre of Excellence for Advance Sensor Technology (CEASTech), Universiti Malaysia Perlis. The electrodes were powered by a direct current (DC) power supply voltage of 16.6 kV. The plasma was generated and bombarded the surface of the samples when the flowing gas penetrates through the quartz glass tube. The treated samples were immediately test for colour, water activity, antioxidant activity and total phenolic content during storage daily for three days compared with untreated samples as control.

Colour parameters measurement

The colour of cooked noodles was measured by Minolta CM-2002 (Minolta Camera Co., Osaka, Japan) with an 11 mm measurement aperture. The colour differences of noodle strands were recorded as Commission International 'Esclairge (CIE) LAB, L^* (lightness), a^* (redness), and b^* (yellowness). L^* value is a measurement of brightness (0-100); a^* value represents the red – green coordinates (- is green while + is red); b^* value indicates the blue – yellow coordinates (- is blue while + is yellow). The instrument was calibrated with a standard white plate before analysis. The DE^* (indicated total colour difference of NMF (T) to the control noodles (NMF (U)) value was calculated using formula as shown below. All measurements were performed in triplicate.

DE^*_{ab} = [(difference of L^* value)^2 + (difference of a^* value)^2 + (difference of b^* value)^2]$^{1/2}$

Where, DE^*, indicated total colour difference of NMF (T) to the NMF (U); L^*, lightness; a^*, redness; b^*, yellowness

Water activity (a_w) measurement

Water activity of the sample was measured using a Decagon's Aqualab Series 3 water activity meter (Pullman, WA) at 25°C. Samples (about 2 g) were evenly placed into plastic cells and were allowed to equilibrate within the headspace of the sealed chamber. The reading was then recorded when the equilibration was achieved.

Preparation of noodles extract

NMF (U) and NMF (T) samples were extracted using ethanol [1:10 (w/v)] at room temperature for 24 hours in an orbital shaker at 170 rpm. Supernatants were filtered through Whatman No. 1 filter paper, and the filtrate was then collected. The extracts were concentrated using a rotary evaporator under reduced pressure at 40°C for 5 hours.

DPPH free radical-scavenging assay

The determination of 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical-scavenging by NMF (U) and NMF (T) were based on the method proposed by Mosquera *et al.* (2007), with slight modifications. DPPH solution is prepared by dissolving it in ethanol. The final concentration of DPPH in reaction mixture is kept at 0.1 mM. All samples and standard were completely dissolved in ethanol and concentration make up to 200 ppm. Each sample in ethanol (2 ml) was mixed with 2ml of ethanol solution containing DPPH radicals. The mixture was shaken vigorously and allowed to stand for 30 min in the dark and room temperature. The absorbance was measure at 517 nm against ethanol as blank. Vitamin C and BHA were used as standard. The radical scavenging activities of the samples were evaluated by comparison with a control (2ml DPPH solution added to 2 ml ethanol). Each sample was measured in triplicate and averaged. The radical scavenging activity (RSA) was calculated using formula:

$$\% \text{ RSA} = [1-(\text{ABS sample}/\text{ABS control})] \times 100\%$$

Determination of total phenolic content

TPC of the NMF (U) and NMF (T) were determined using a Folin–Ciocalteu (FC) assay based on the method described by Alothman *et al.* (2009), with some modifications. In brief, extracts (1 mg) of NMF (U) and NMF (T) were dissolved in 4 ml of ethanol. Furthermore, 400 µl of the resulting solution were mixed with 2 ml of FC phenol reagent. The reagent was pre-diluted, 10 times, with distilled water. After standing for 5 min at room temperature, 1.6 ml of (7.5% w/v) sodium carbonate solution was added. The solutions were mixed and allowed to stand for 1 hour at room temperature. The absorbance was measured at 765 nm, using a UV–visible spectrophotometer. A calibration curve was prepared, using a standard solution of gallic acid. Results were expressed as percentage of gallic acid equivalents per hundred grams of freeze dried extract.

Statistical analysis

SPSS software version 16.0 (SPSS Inc., Chicago, IL, USA) was used to perform statistical analysis. Average values from triplicate experiments were obtained and One-way analysis of variance (ANOVA) followed by Tukey's test was performed to determine the differences in mean values of achieved data from different sample types. Statistical differences were considered as significant at $p < 0.05$.

Results and Discussion

Colour parameters determination

The lightness value *(L^*)* was higher for untreated samples than for treated samples, while a greater increased in the redness *(a^*)* and yellowness *(b^*)* values were observed for the treated samples. There was no significant different ($p>0.05$) in the lightness value *(L^*)* of the NMF (U) noodles sample in day 0 until day 3 storage. However, mango noodles sample treated with ACP showed a significant different ($p<0.05$) in the L^* values on day 0 as compared to sample stored on day 3. No significant different ($p>0.05$) was detected in day 1 and 2 storage for L^* colour values. Similar observations were also reported by earlier researchers (Sangnark and Noomhorm, 2004; Anil, 2007; Mohamed *et al*., 2009) wherein, substitution of high dietary fibre flour into the bread resulted in dark colour. This revealed the reason why NMF lightness were 62.70 for untreated and 61.09 for treated samples on the day 0 after preparation.

The redness colour value *(a^*)* differ significantly ($p<0.05$) for NMF (T) throughout the storage period compared to NMF (U). Both samples of NMF (U) and NMF (T) showed no significant different ($p>0.05$) in the b^* colour values, indicating the yellowness of the NMF (U) and NMF (T) samples remained the same. Among investigated samples there were a visual differences in red colour for NMF (T) versus NMF (U) samples, since colour change DE^*_{ab} = 3.5–5.8 reflects easily noticeable colour

Table 1. CIE colour parameters values of NMF (U) and NMF (T) mango flour noodles with ACP.

NMF	Colour parameter	Day 0	Day 1	Day 2	Day 3
Untreated	L*	62.70±2.54^{b}	62.64±0.99^{b}	61.95±3.15^{b}	55.19±4.91^{ab}
	a*	8.49±0.61^{ab}	8.65±0.26^{b}	8.38±0.25^{ab}	8.48±0.31^{ab}
	b*	24.05±1.73^{ab}	25.16±0.68^{ab}	27.71±1.03^{b}	25.87±2.03^{b}
Treated	L*	61.09±2.56^{b}	58.79±0.51^{ab}	56.56±2.12^{ab}	53.05±3.29^{a}
	a*	7.38±0.28^{a}	9.91±0.61^{c}	9.11±0.16^{bc}	11.86±0.71^{d}
	b*	21.14±0.85^{a}	26.07±1.01^{b}	25.69±3.18^{b}	28.10±1.05^{b}
ΔE^*_{ab}		3.51±0.78^{a}	4.24±0.93^{a}	5.80±1.54^{b}	4.58±4.67^{a}

The values that do not share the same letter in the same row are significantly different ($p<0.05$)

difference (Table 1). Literature reports various results with regards to colour change and plasma treatment, examples for tomato and lettuce during 3 min caused colour changes that was higher than 4.47 and 9.63, respectively (Bermudez-Aguirre *et al*., 2013).

Water activity (a_w)

According to Neri *et al.* (2010), water activity (a_w) determines the availability of water (free water) for deterioration of food and hence shortens the shelf life of food. Edwards (2007), reported that the aw is the water available to be used in physical, chemical or biological reactions. aw is a vital parameter to be determined to monitor the products quality and safety. It is defined as the water available to be used for the microorganism growth and changed in the physical or chemical properties of the products (Markova and Wadsö, 1998).

The aw of NMF (U) on day 3 (0.97) was found to be significantly ($p< 0.05$) higher than the NMF (U) on day 0 (0.91). Hou (2010) classified aw values ranged for wet noodles are from 0.95 to 1.00 as highly perishable food. Thus, both samples, NMF (U) and NMF (T) fell into the high moisture or high aw product. aw for NMF (U) showed a significant different ($p<0.05$) values throughout storage period (Table 2).

The values increased significantly ($p<0.05$) as the samples started to deteriorate throughout the storage period as the increment in aw contributed to the bacteria growth. Mango noodles that had been treated with ACP (NMF (T)) showed constantly lower values as compared to the NMF (U) throughout the storage period. This may be due to ACP effects on the aw of the treated noodles samples. The phenomena could be further exploited in the future.

Antioxidant activity

The plot of the antioxidant activity versus storage days (Figure 2.) shows that the percentage of RSA antioxidant activity of the NMF (U) and the NMF (T) decreases during the three days storage period. For the NMF (U) samples, the activity decreases from the initial value of 46.2% for day 0 to 41.4% at day 3 of storage period. For the NMF (T) antioxidant activity decreased from 44.1% at 0 day to 41.3% at day 3. Both NMF (U) and NMF (T) showed a linear decreasing trend with R^2 of 0.988 and 0.79 respectively. The rate of decrease in antioxidant activity was lower (1.03) in the treated sample as compared to the untreated sample (1.57). It was also observed that there is a significant different ($p<0.05$) in both NMF (U) and NMF (T) between day 0 and day 3 for antioxidant activity percentage. However, no significant different ($p>0.05$) was recorded from day 1 to day 3 of both NMF (U) and NMF (T) samples for antioxidant activity percentage. The result shows that ACP preserves the antioxidant activity in the noodles.

The above values are in accordance with the results from Maryam and Mahmood (2016), based on the 11 min plasma jet treatment on fresh walnuts. Although the antimicrobial effect of cold plasma has been investigated in many articles, only one study was found that examined the effect of cold plasma on the antioxidant capacity of fruit. Ramazzina *et al.* (2015) reported the DBD plasma treatment did not

Table 2. Water activity (a_w) for untreated and treated mango flour with ACP.

Noodles	Day 0	Day 1	Day 2	Day 3
NMF(U)	0.91±0.01^{a}	0.92±0.02^{ab}	0.93±0.01^{b}	0.97±0.01^{c}
NMF(T)	0.90±0.01^{a}	0.91±0.01^{a}	0.91±0.01^{a}	0.92±0.01^{ab}

The values that do not share the same letter in the same row and column are significantly different ($p<0.05$).

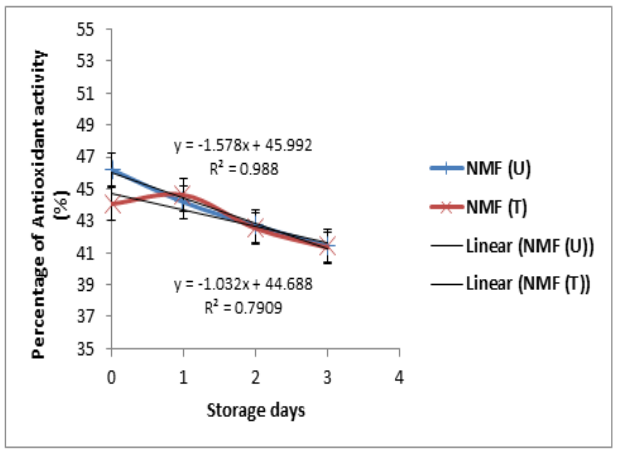

Figure 2. Antioxidant activity of the NMF (U) and NMF (T) samples during the 3 day storage period.

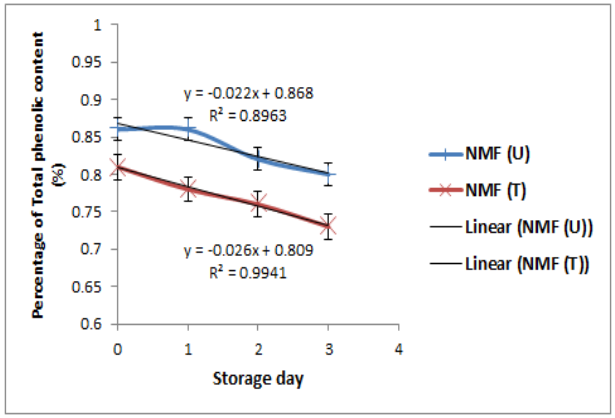

Figure 3. Variation in the TPC of NMF (U) and NMF (T) over 3 days storage period.

affect the antioxidant activity and antioxidant content (DPPH and FRAP) of kiwifruit.

Total phenolic content

The TPC versus storage period was also plotted to establish the trends in the samples as shown in Figure 3. The initial TPC value in the NMF (U) was found to be 0.86% however to be insignificantly different ($p>0.05$) throughout the 3 days storage period. On the other hand, the NMF (T) samples showed a significant different ($p<0.05$) on the 0 day compared to the third day of storage. Sarangapani *et al*. (2016) reported that the effect of plasma in TPC of parboiled rice flour, increased significantly ($p < 0.05$) for 30 W and 40 W for 5 min sample respectively. Increased phenolic content after plasma treatment is attributed to the release of phenolic compounds from glyosidic components and the degradation of larger phenolic compounds into smaller ones. However, possible decrease in TPC is due to the reaction of these phenolic compounds with the free radicals which leads to possible oxidation of phenolic compounds (Sarangapani *et al.*, 2016).

These results found to be similar with the reports of previous works with irradiated samples (Beaulieu *et al*., 2002; Breitfellner *et al*., 2002; Fan *et al.*, 2003; Hanotel *et al*., 1995).

Conclusion

ACP treatment, a novel technology in value added mango flour noodles processing showed promising results from the research. Good preservation of antioxidant and total phenolic content were obtained after the treatment. The color analysis, aw, antioxidant activity and total phenolic content did not show any critical changes after the treatments. The results showed that atmospheric cold plasma processing are suitable non-thermal processing technologies to preserve the quality and functionality of value added noodles containing mango flour throughout storage period. Further studies would probably focus on microbiological test on plasma treated mango noodles.

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