Atmospheric Pressure Cold Plasma (ACP) Treatment a New Technique to Improve Microstructure and Textural Properties of Healthy Noodles Fortified with Mango Flour

Noor Shazliana Aizee Abidin[1], Ibni H. Rukunudin[1], Siti K. Zaaba[1], Wan A. W. Omar[2]
[1]Pusat Pengajian Kejuruteraan Bioproses, Universiti Malaysia Perlis (UniMAP), Kompleks Pengajian Jejawi, 02600 Arau, Perlis, Malaysia.
[2]Institut Perubatan dan Pergigian Termaju, Universiti Sains Malaysia, Bertam, 13200, Kepala Batas, Pulau Pinang, Malaysia.
shazliana@unimap.edu.my

***Abstract*—The effect of atmospheric pressure cold plasma (ACP) on microstructural, textural and sensory properties of healthy noodles fortified with mango flour was studied. Atmospheric pressure cold plasma was carried out using helium gas with a flow rate of 1000 ml/min at room temperature. The electrodes were powered by a direct current (DC) power supply voltage of 16.6 kV wrapped around the quartz glass tube to develop plasma plume. SEM for microstructural observation was done to study the changes in surface morphology of plasma treated noodles. It was observed that after the plasma treatment the gluten and fiber content on the noodles surface more coherent and smoother between gluten network and starch granules than the control with respect to plasma power and time of treatment. Atmospheric pressure cold plasma treatment maintained the hardness, springiness and gumminess of control noodles without mango flour (CNT) and noodles fortified with mango flour (NMFT) significantly (P<0.05) compared to untreated control noodles (CN) and untreated mango flour fortified noodles (NMF). The results suggest that ACP is an effective technique for enhancing the gluten strength and improving the qualities of noodles fortified with mango flour.**

***Index Terms*—Atmospheric Pressure Cold Plasma; Mango Flour; Noodles; SEM Microstructure; Sensory Properties; Texture.**

I. INTRODUCTION

Noodles are popular foods in a lot of Asian countries, prepared by using primary simple item consist of wheat flour, salt and water. Noodle is proclaimed to be deficient in the important dietary element in the form of nutritive fibers, antioxidants and bioactive compounds, which are vanished through wheat flour refinement. Therefore, noodles that signify a main usage of flour is relevant to be fortified with composite flour as an added value product for health as it improves the essential nutrients and benefits.

The consumption of added value products take place as people are more towards a healthy lifestyle is one of the factors of the growing awareness of diet and health, as well as new processing technologies [1]. Ready-to-eat added value products such as noodles, bread and biscuits turn out to be a crucial part in the ration industry because of their uniqueness of staple, adjustable caloric content and active promotion of using fruit as a basic substitution component of a healthy diet. Hence, innovative interest in food industry requires the improvement of novel soaring and quality convenient added value products attuned to a healthy diet.

Plasma is a matter that contains partially or wholly ionized gas with a net neutral charge and is often referred to as the fourth state of matter as it shares properties similar to both those of gases and liquids. One of the most common forms of artificially produced plasma is the fluorescent or neon light. In more recent years the application of low-temperature plasmas at both atmospheric and low pressures to heat sensitive surfaces has evolved. There has been much already published in the literature about the effect of plasmas on the inactivation of bacterial spores, particularly *Bacillus atrophaeus* (subtilis), which provides a common target for attempted comparisons between different plasma technologies and with heat inactivation [2].

Mango flour noodle is an added value product source of phenolic and possesses high antioxidant activity. It is important to evaluate the effect of cold plasma on the textural, microstructural and sensory properties of mango flour noodles immediately after treatment compared to the untreated sample. Several researchers have reported that the cooking and textural properties of the rice can be altered using nonthermal processing techniques like ultrasound, gamma irradiation, etc. [3] and [4]. However, the uses of plasma technique to improve properties of fortified noodles are not explored yet. Thus, the aim of this study was to determine the effect of atmospheric pressure cold plasma on microstructural and textural properties of freshly prepared mango flour noodles.

II. MATERIALS AND METHODS

A. Materials

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

B. Mango Flour (Mangiferaindica 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 the flour using a laboratory scale mill.

C. Noodle Preparation

Noodles formulation of 100% wheat flour and with 3% of mango flour ratios to 97% wheat flour w/w, were blended in a noodles mixer (Automatic noodles and pasta machine) with a 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 wheat flour treated (CNT) and noodles from mango flour treated (NMFT) and with ACP were compared to wheat (CN) and mango flour noodles (NMF) untreated with ACP served as control noodles respectively.

D. ACP Treatment on Mango Flour Noodles

ACP was set up as shown in Figure 1 with two copper electrode wrapped around the quartz glass tube that has the outer diameter of 2.0 mm and the 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.

A sample of treated noodles was exposed to the ACP for 5 min after cooking. Helium gas with a flow rate of 1000 ml/min was used as the main gas source. The gas flow rate was controlled by the gas system controllers developed in Centre of Excellence for Advanced 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 tested for microstructural surface analysis using SEM and texture profile analysis compared with untreated samples as control.

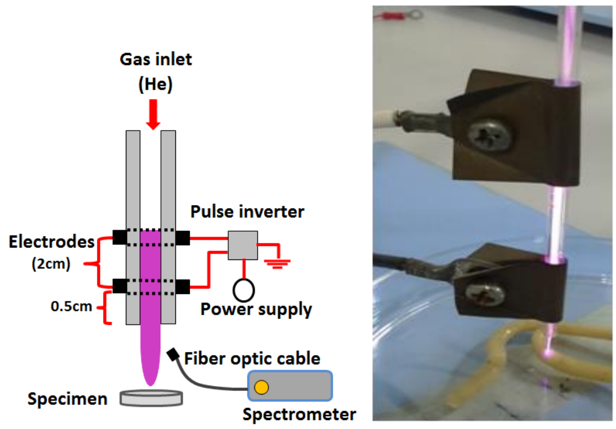


Figure 1: Plasma jet device and plasma when exposed to the sample.

E. Microstructure of Noodles Surface

In order to understand the changes in the surface of noodles morphology caused by plasma, the surface was sputter-coated with platinum for 10 minutes and observed by scanning electron microscopy (Jeol, Tokyo, Japan).

F. Texture Profile Analysis

Textural profile analysis (TPA) of cooked noodle was determined using a Texture Pro CT Texture Analyzer (Brookfield Engineering Labs). Cooked noodles were prepared by removing the excess water on noodle surface, the drained noodles were placed in a covered container and three uniform long noodle strands were taken and cut to a length of 6.0 cm. Five short strands were randomly selected and placed side by side on the base plate, and compressed with a TA7 knife edge probe by using a 5 kg load cell. The compression strain was 70% of the noodle thickness, and the averages of at least eight analyses were calculated. Five textural parameters, including hardness, cohesiveness, springiness, gumminess and chewiness were recorded from the TPA.

G. Statistical analysis

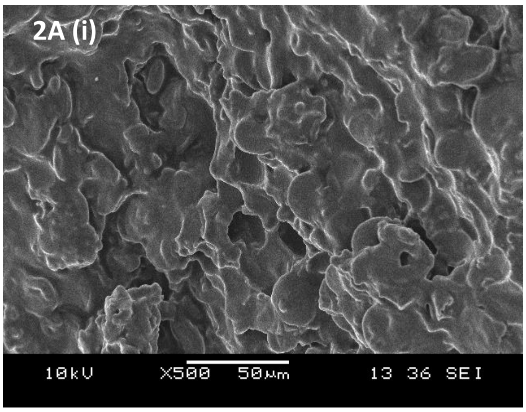
All measurements were performed at least in triplicate. Statistical analyses were carried out with SPSS 16.0 for Windows, using one-way analyses of variance (ANOVA). $P<0.05$ was considered to be significant by using Tukey's test.

III. RESULT AND DISCUSSION

A. SEM Microstructure

The surface of noodles was examined using Scanning Electron Microscopy at magnifications of 500x (Figure 2A and 2B). The surface structure of noodles was heavily covered by non-uniform amorphous gluten protein. The starch granules (both for wheat noodles untreated and treated CN and CNT) were embedded deeply in the gluten network (Figure. 2A). Morphology of mango flour noodle surface, both for untreated and treated (Figure. 2B) differed greatly from wheat noodles. Mango flour noodles appeared to have a different protein-starch binding pattern, where the NMF and NMFT cell wall appeared to align and form part of the noodles surface structure with irregular and discontinuous matrix around the starch granules. However, the formation of continuity starch-protein matrix was disrupted by the addition of mango flour in conjunction with the treatment of ACP for NMFT.

No apparent distinction was observed on the micro-morphology of the surface between controls and samples treated with ACP. However, the surface of noodles treated with ACP (CNT and NMFT) were more coherent and smoother between gluten network and starch granules than the controls without ACP treatment (CN and NMF), indicating that ACP treatment could improve the surface connectivity between starch granules and gluten for noodles, which may further influence the surface properties of cooked noodles [5].



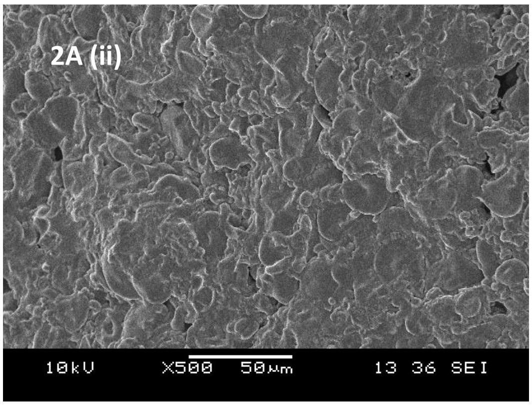


Figure 2A: (i) Untreated wheat noodles (CN) and (ii) Treated wheat noodles (CNT), SEM Micrographs at 500x noodles magnification

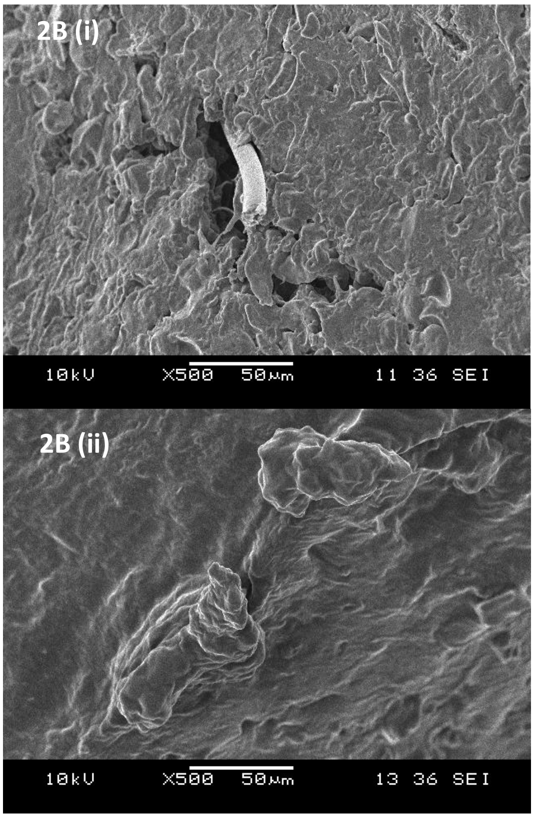


Figure 2B: (i) Untreated mango flour noodles (NMF) and (ii) Treated mango flour noodles (NMFT). SEM Micrographs at 500x noodles magnification

B. Texture Profile Analysis

From the Table 1 it can be seen that the cold plasma affected the textural properties of noodles. The hardness and springiness are the important parameters which are considered for the texture evaluation and consumer acceptability [6]. There is a significant difference ($P<0.05$) between the treated and untreated samples for hardness. This result contradicts with hardness reported by Thirumdas et al. [7] suggesting that leaching components can be responsible for a decrease in hardness and an increase in adhesiveness of cooked rice samples differed in noodles samples.

Prasert and Suwannaporn [8] defined that the chewiness is the number chews required for the cooked rice suitable for swallowing during mastication. Chewiness tends to increase when treated in plasma. The increase in hardness is directly correlated to chewiness, which shows that more work is required to chew the noodles plus with the addition of mango flour make the noodles more chewable. Control sample had a cohesiveness of 0.65, which was increased to 232.3 and 244.0 in plasma treated noodles CNT and NMFT respectively. There is a significant difference found for springiness and gumminess after the treatment of both types of noodles compared to untreated samples.

Table 1
Texture Profile Analysis of ACP Treated Noodles

	CN	CNT	NMF	NMFT
Hardness (g)	101.33 ±3.21^a	232.33±6.81^b	107.67±8.62^a	244.00±9.17^b
Cohesiveness	0.65±0.02^a	0.86±0.03^b	0.7100±0.01^c	0.8867±0.01^c
Springiness (mm)	1.12±0.03^a	1.43±0.03^c	1.38±0.02^b	1.25±0.02^c
Gumminess (g)	78.00±1.00^a	196.67±2.08^c	92.00±1.00^b	195.00±5.00^c
Chewiness (mJ)	0.77±0.05^a	2.700±0.10^d	1.27±0.12^b	2.33±0.06^c

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

IV. CONCLUSION

Results from this research clearly showed that noodles fortified with mango flour at3% level treated with atmospheric pressure cold plasma (ACP) have a significant impact on the microstructure and texture profile analysis. SEM micrographs showed that noodles treated with ACP significantly ($P< 0.05$) improved the noodles gluten strength and texture. These improvements were not observed in both control noodles and mango noodles untreated with ACP. The obtained results from physical analyses are explained by the SEM analysis; it can be observed that noodles from both control wheat and mango flour treated with ACP had more consistent and even linkage between gluten network and starch granules which could result in improving the hardness, springiness and gumminess of noodles texture that can be similar to pasta.

ACKNOWLEDGMENT

The authors thank Ministry of Higher Education of Malaysia for the scholarships, Universiti Malaysia Perlis (UniMAP) and Centre of Excellence for Advanced Sensor Technology (CEASTech), UniMAP, for the use of ACP equipment.

REFERENCES

[1] Danalache, F., Mata, P. and Mold, M. (2015). Novel mango bars using gellan gum as gelling agent: Rheological and microstructural studies. LWT - Food Science and Technology 62, 576–583.
[2] Philip, N., Saoudi, B., Crevier, M., Moisan, M., Baarbeau, J., & Pelletier, J. (2002). The respective roles of UV photons and oxygen atoms in plasma sterilization at reduced gas pressure: the case of N2eO2 mixtures. IEEE Transactions on Plasma Science, 30, 1429-1436.
[3] Cui, L., Pan, Z., Yue, T., Atungulu, G. G., & Berrios, J. (2010). Effect of ultrasonic treatment of brown rice at different temperatures on cooking properties and quality. Cereal Chemistry, 87, 403–408.
[4] Sung, W. C. (2005). Effect of gamma irradiation on rice and its food products. Radiation Physics and Chemistry, 73, 224–228.
[5] Ross, A. (2006). Instrumental measurement of physical properties of cooked Asian wheat flour noodles. Cereal Chemistry, 83, 42–51.

[6] Chen, H. H., Chen, Y., & Chang, C. H. (2012). Evaluation of physicochemical properties of plasma treated brown rice. Food Chemistry, 135, 74–79.
[7] Thirumdas, R., Deshmukh, R. R., & Annapure, U. S. (2015). Effect of low temperature plasma processing on physicochemical properties and cooking quality of basmati rice. Innovative Food Science & Emerging Technologies, 31, 83–90.
[8] Prasert, W., & Suwannaporn, P. (2009). Optimization of instant jasmine rice process and its physicochemical properties. Journal of Food Engineering, 95, 54–61.